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A METHOD FOR DETERMINING TASK STRATEGIES

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Silver Spring, Maryland

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This technical report has been reviewed and is approved.

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Approved for publication.

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This study is an extension of task analysis methodology. The concept of strategic principles or task strategies implicit in the job activities of highly proficient performers is examined with the intent of improving training. The goal is to identify or invent such strategies, as appropriate, and then proceed with training encouraging use of them. A set of 25 information processing functions is described along with examples of strategic principles and training implications. Certain other strategic principles not readily interpretable in information processing terms are presented also. An analytic procedure for determining and/or devising strategies is provided and suggestions on the teaching and learning of strategies are summarized.

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SUMMARY

Problem

Descriptions and analyses of human performance are used extensively in the Air Force. Examples of uses are in planning new systems and procedures, in human engineering equipment for effective use by humans, in personnel planning, and in the development of training programs and technical data (Technical Orders and Job Performance Aids). In general, current descriptions and analyses represent the overt facets of the step-by-step performance of a novice. Seldom do they depict the smooth and coordinated performance of the highly skilled and efficient performer; and even more significantly, they fail to reveal those "tricks of the trade" or grand strategies that mark a virtuoso.

This failure to describe proficient performance has several undesirable consequences. One of the most significant such consequence, and the one of primary concern in the present effort, is that when current task descriptions (or task analyses) are used to specify the goals or objectives of training programs, the lesser goal of "novice performance" is accepted rather than systematically seeking the best path to the highest degrees of proficiency.

As a first step toward techniques for describing and analyzing skilled performance, a conceptual framework is needed to sensitize the observer to the characteristics of truly proficient performance and to help him describe those characteristics. Further, to facilitate the development of training programs that promote the attainment of highly skilled performance, some systematic discussions are needed of the conditions that promote the development of those unique features of highly skilled performance. The present report represents an attempt to fulfill these needs.

Approach

The basic approach was to conceptualize the human performer as an information processing system and describe those unique features of skilled performance in terms of information processing, especially the strategy of information processing. Five major features of skilled performance were described and interpreted as changes in the strategy for processing information. General techniques were suggested for detecting or inventing improved information processing strategies, and thereby improving skill level. And, finally, suggestions were made for helping novices acquire improved strategies for processing information. A broad range of examples were developed to help the reader understand and accept the author's basic conceptualization of skilled performance and become more able to recognize and describe skilled performance.

Results

Changes in performance with practice were characterized by: (1) progressive decrease in the awareness or cognition needed to perform the elements of the task, (2) progressive decrease in the effort required to perform the task and an increase in stereotyped behavior, (3) increase in capacity to resolve uncertainties, (4) reduced dependence on specific real-time information in the task, and (5) increased ability to group input data into meaningful units and schedule the output smoothly. These characteristics of skilled performance were viewed as changes in the strategy for processing information.

Twenty-five terms associated with information processing were discussed. The discussion includes the use of each term to detect, characterize or describe the unique differences between skilled and unskilled performance of a variety of tasks.

Using his discussion of the above two topics, the author outlined a procedure for detecting or inventing strategies that distinguish skilled from unskilled performance of a given task. In general, the process involves analyzing the job (including the general goal and major steps) in transactional (information processing) terms and, following some simplification, creating and testing a strategy that most adequately fulfills the criteria for the accomplishment of the goal or mission.

The prime contribution of the report to the planning of training pertains to specifying the objectives of training. More specifically, the report should promote and facilitate the rather detailed description of highly skilled performance as the true objectives of training. In addition, the report provides some specific

suggestions for the design of training conditions for the acquisition of high levels of proficiency. One such suggestion is to encourage student interaction and confidence in the training conditions. Other suggestions are to practice in a realistic total context of the job, progress from easy to more complex, and adapt instruction to individual differences.

An appendix provides detailed accounts of developing task strategies for skilled performance of five quite different jobs (parts buyer, disassembly and assembly, loading and unloading a delivery truck, setting up a filing system, and detailed visual inspection of a complex part). Also provided are brief accounts of essential differences in strategy between skilled and unskilled performance of six other jobs.

Conclusions

This report does not provide detailed prescriptive guidance suitable for immediate use by practitioners who may seek, for a variety of reasons, detailed descriptions of those elusive but powerful features that distinguish the performance of a novice from the performance of a virtuoso. However, the report does provide a sensitive and often useful, account of some of those uniquely distinguishing features of skilled performance. Also, it provides a general conceptual framework, and some practical suggestions, for detecting and describing such features for many uses in the Air Force.

PREFACE

This report represents a portion of the research program of the Advanced Systems Division, Air Force Human Resources Laboratory. The report was prepared by American Institutes for Research, Silver Springs, Maryland, under Air Force Contract F33615-72-C-1014. The work was documented under Project 7907, "Conditions of Effective Training and Transfer," as Work Unit 79070003, "Task Analysis Methods that Especially Depict Skilled Performance." Dr. Ross L. Morgan was the project scientist and prepared the summary. Dr. Theodore E. Cotterman was the work unit scientist and technical monitor of the contract.

The author's thanks are due to Dr. Robert W. Stephenson, Principal Research Scientist, American Institutes for Research, for suggestions early in the study. Acknowledgment is also due Mr. Clifford P. Hahn, Director, Human Resources Research Institute, American Institutes for Research, for editorial recommendations that led to some technical clarifications, and to Colonel Warren P. Davis, USA (Ret.) for a number of highly pertinent examples which, although lost in shortening the text, illuminated a number of ideas. Deep gratitude goes to Halaine Gary who generally enhanced the readability of the several versions of this report.

AUTHOR'S PREFACE

In my early publications on task analysis and task description, I was concerned about additions to the "Situation-Response-Feedback" paradigm This was not because it was incorrect for many purposes, but because I knew it to be incomplete. I wrote of the importance of anticipating human error liabilities (and gave examples) and expressed worries about the identification of "contingencies." The work on systematic troubleshooting strategies with Jack Folley was a significant example of a training problem that didn't fit the S-R-F paradigm.

In more recent years I have been associated with the creation of "system design principles." These principles were really forms of optimizing strategies. They included the design of man-machine interactions at problem solving levels. This turned my attention to levels of human performance above that of mere performance of explicit procedural rules. It became clear that these rules composed a kind of minimum substrate for skill. A mature competence was manifest in various optimizing principles that coped with uncertainties, scarce resources (including time), and modified procedure to suit the circumstances. This competence included but was not restricted merely to "tricks of the trade." This line of thought prompted me to review many of my own experiences in some variety of learning situations and aspirations.

It became increasingly clear that formal training should and could extend beyond the learning of procedural rules. Indeed, problem solving and decision making do not readily fit into rules, although they do fit into what I thought of as "behavior formats." I gave the rather hackneyed name of "strategies" to these higher levels of skill and sought an opportunity to think through the issues but with a tangible objective in view. This objective consisted of two parts: to use a task description scheme with which I was familiar in information processing as a basis of organizing behavioral and work strategies for reference purposes, and where this was incomplete, propose a technique for designing teachable and learnable "strategies."

That effort resulted in a large compilation of transactional analyses, functional variables, principles and examples. Of necessity there was extensive redundancy within and between treatments of functions because indeed functions in real life are rarely if ever mutually exclusive. My editors persuaded me to reduce this mass of material to a report which could be held in one hand so that a readership of reasonable size could be reached. The present version is the result of that revision. I trust that it is not unduly cryptic.

The scope of time and effort did not allow extensive literature search, so that no doubt a number of specific acknowledgments that ought to be made have not been made. In any event, these acknowledgments would have been *ex post factor* to the writing. It seemed better to avoid references altogether rather than offer a small scale sample. There are ample indications that at least some of the cognitive theorists of the past decade are evolving conceptual models of perception, long and short term memory and behavior organization at least consistent with the propositions I have proposed.

I would like to see–and help bring about–the same kind of intensive professionalism brought to the training of, say, the secretary, the coding clerk and the baggage handler–as well as pilot and navigator–that is given to virtuosity in professional sports and the fine arts. In these latter, the higher reaches of competence training are almost exclusively "strategic" in nature. I trust the present study will contribute at least modestly to those who share this aspiration.

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I. OBJECTIVES

The major purpose of the entire inquiry was to better the ability of formal training operations to bring a student not merely to acceptable levels of procedural performance, but to high levels of on-the-job competence. It is well known that the "pro" acquires many tricks of the trade, operating strategies, short-cuts, and other devices that tend to make him not only more effective, but effective at less cost to himself. He "learns" how to use himself more efficiently as a processing entity. Some individuals are better—and more lucky—in learning these things on the job, given time and opportunity. But to the extent that this job "wisdom" can be made explicit as a training requirement, and formalized in the training experience, there need be less dependence on the haphazard nature of job experiences.

For present purposes, let us group these kinds of higher-order competence under the term "work strategies" and sort out the differences later. In his development of training requirements the task analyst at present has a variety of techniques for identifying the procedural information about job tasks. We would like to extend these task analysis techniques to the identification and description of work strategies leading to levels of competence above that of bare procedural mastery. Hopefully, the procedure for specifying the analysis and synthesis of work strategies will be in a context that clearly points not only to training implications, but to training content and procedure.

Work strategies can be subdivided into two classes. What might be called "behavior strategies" consist of techniques intended to maximize the operator as a processing resource. Thus, he learns techniques which specifically offset certain types of error, or which increase the amount of task information he can process in a given amount of time, or increase his reliability in performance. When the driver deliberately increases the range and frequency of his scanning with increase in his anxiety to reach a goal, we have an example of a behavior strategy. He is (deliberately) compensating for his tendency to tunnel perception under stress.

On the other hand, a "task strategy" is a technique for coping more eff ively and efficiently with the uncertainties of a work environment. Thus, if the driver expands his range of scan and frequency of sampling as he accelerates his vehicle, he is responding strategically to the increasing risk caused by greater speeds.

The distinction between a task strategy and a behavior strategy is only a pragmatic one. It helps generate a program for analysis of work situations that is comprehensive. When the strategy is embedded in a competence, it makes no difference what its antecedents may have been.

The Problem

In some cases work strategies can be found by direct questioning of task incumbents. But in many cases, the expert performer is unable to identify and describe his strategies. This fact was demonstrated years ago in attempts to find troubleshooting procedures. Observation by the task analyst may be insufficient because the essential strategic components may be camouflaged by secondary or irrelevant activities or the implicit strategy may not be used reliably in practice. In these cases, the task analyst may have to recognize the applicability of a strategy known in another work context and adapt it. Failing such a reference, he may have to "invent" the strategy.

The practitioner will therefore need the guidance of a procedure for analysis and invention. He should also have reference to a body of information about work strategies. The content of work strategies should be subdivided into those dealing with behavior tendencies and those dealing with task environments. Ideally, an organized structure—like a loose checklist—would support systematic examination of tasks and missions. Since the subject matter rules out a cookbook set of procedures for generating strategy content, there must be heavy dependence on the expertise of the task analyst. Ultimately, a special training in the art of strategy design may become available.

The task set for the present study was therefore the development of some core reference material on behavior tendencies, many examples of behavior strategies and task strategies, and an outline of a procedure. The procedure should aid in identifying situations that might profit from strategy content in training and guide in the analysis and design of such strategic content.

Rationale for Layout of the Report

The main report is structured like a training document for practitioners. Section II is an organized summary of general behavior tendencies that accompany extended practice, both in the formal training environment and on the job. It is an abstract of content scattered in Section III. The latter is a series of some twenty-five essays on each of a set of information processing functions. These functions have been developed and used informally by the author in previous contexts of system analysis dealing with human behavior, automatic information processing systems, and combinations of both. Section III is proposed as a relatively exhaustive of the classes of information processing of humans in task environments. Section IV shifts to classes of task strategy in work environments not readily fitted into the information processing structure. The universe of task strategies is open-ended; thus, it can only be sampled in the text. Section V describes a procedure for analyzing work situations and devising strategies relevant to training. This section also states assumptions about the expertise and background knowledge of the practitioner and qualifications about the procedures. Section VI summarizes some suggestions on the teaching and learning of strategies that have been scattered throughout the text in more specific situations. The Appendix gives some brief examples of strategy development in selected real world contexts. Rather than to cite dramatic outcomes, the intent in these examples is to suggest how to think about work environments so as to foster ideas about strategy.

The intent of the main report is not only to provide a backdrop of knowledge and technique, but to expose the practitioner to a way of thinking about human behavior and work situations that will be conducive to perceiving the optimizing factors and principles frequently hidden in a morass of procedural data in a task analysis.

II. THE OPERATOR AS AN ADAPTIVE SYSTEM

The design and inculcation of behavior strategies is intended to mitigate the limitations and liabilities of the operator as a processing system coping with a complex and often unpredicatable environment. We should therefore try to get a picture of his behavioral tendencies, and especially of the pattern of their changes in the normal process of learning experiences during and after formal training. We will see that as the operator develops certain kinds of proficiency, the organization of his behavior tends to change, and at least some aspects of proficiency may incur some risks and penalties.

The concept of the operator as an information processing entity enables us to think of him as a system. As the information necessary and sufficient to elicit a response or response pattern changes with practice of various kinds, we can posit a reorganization of the internal control structure that mediates between (a) inputs to the operator and operator purpose and (b) the operator's responses. The concepts of control hierarchy and changes in that hierarchy leading to greater efficiency, effectiveness, reliability, and flexibility in performance justify thinking of the operator as an adaptive system. It is axiomatic that, other things equal, increases in the efficiency in the operation of a system exact penalties in at least some aspects of performance, although a net gain may be made in overall performance. The skilled touch typist may be completely incapacitated from typing by an injured forefinger, but the hunt-and-peck typist may be merely inconvenienced by using a substitute finger. By understanding these tradeoffs in specific terms, training may be organized so as to minimize the liabilities of these self-organizing processes.

The following are capsule statements of self-adapting principles that operate in extended practice.

Progressive Autonomy in Hierarchical Organization

In cognitively-directed behavior, mediating processes at the level of self-instructions tend progressively to reduce with extended practice. What originally required attention and symbolic action in perception, recall of processing rule, and control of effector response becomes with repetitive practice virtually automatic. This frees attention for handling the unexpected, for retaining short-term task information and for the development and reinstatement of longer-term anticipations. The liabilities are principally in the loss of degrees of freedom in cognitive intervention that may be required *within* habitual units of automatic behavior. These difficulties may appear in perceptual, processing, or motor behavior, or a combination of them. Obviously, this progressive autonomy is necessary for acquiring a skill. But suitable programming of exercise material may prevent undue freezing of behavior units, and a retained overlay of cognitive control can provide habit redundancy at a more flexible level.

Progressive Least Effort

The adaptive processing system will "seek" and apply the minimum demand for facilities in the processing of messages. This principle is not independent of the preceding one. Its moderate extension is seen in "routinized" behavior; in extreme manifestation, it is stereotyped behavior. A number of processing variables are involved. *Other things equal,* the clarity of the goal image becomes reduced, and the goal image may cease to be functionally active as criterion information. Sampling of input data tends to become rigidly formatted and reduced in range and frequency. Processing formats get established with restriction to routine input variables, processing rules, and limited range of output patterns. Selected domains of memory content become directly available as a restricted set. Sampling of feedback becomes restricted and localized to autonomous levels of control. The smaller the range of variations demanded in task performance, the more rapidly will these conditions obtain. In themselves, these processes are enormously adaptive, and they should be interfered with only when they reach a level of liability not appropriate to the work situation or the worker.

Progressive Uncertainty Management

Uncertainty as to situational status, input data, processing rule, or output organization tend to deadlock the novice. With extensive practice, the operator tends to develop hypotheses, probes, and feint responses for breaking his internal deadlocks. He may develop the equivalent of a cointossing device in order to avoid paralysis. In principle, behavior becomes organized so as to minimize subjective uncertainties which use up channel capacity.

Minimized Dependence on the Environment

With much task practice, the operator increasingly projects anticipations, plans, meanings, formats (conceptual models) upon the work environment. Increasingly, input information is filtered selectively by these formats, so that there is not only a restriction in the frequency of sampling, but also a standardization of the data variables that are sampled. The overall effect is an increased dependence on the implicit model or plan and decreased dependence on redundancies in the live data from the environment. Without deliberate interventions, the ultimate level of balance that is stabilized will probably depend on the frequency and severity of aversive consequences perceived by the operator. It should be emphasized that the anticipations, plans, and formats become implicit and below the level of the operator's awareness.

Increased Coding Efficiency

With large amounts of practice, the operator ceases to respond to individual stimulus elements as such, but to their patterns and contexts. This may be thought of as responding to the "meaning" of a pattern of input data. The retention of a "meaning" enables many elements of data to be treated as a "chunk" and is more readily stored in working memory and used for access to long-term memory, or for recoding. Perhaps its most important adaptive factor is that it gives the operator greater temporal independence between the physical occurrence of the input data and the physical temporal requirement for output response. This temporal independence between input rates and output rates of response has large load-levelling implications for the operator. This tendency for complex systems to use load-levelling strategies, both among their internal components and between the system and its environment, constitutes another principle of system organization.

III. INFORMATION PROCESSING STRATEGIES

The following twenty-five information processing terms are the writer's extension of his earlier half-dozen categories used by him as a generalized task structure. Like them, the present set can be more or less grouped under the functions of input–processing–memory–output. The rationale for the present set and their transactional definitions have been described elsewhere. They, and the strategic principles associated with them, seem valid for the design of automatic as well as human information processing systems, or combinations of both. In a real sense, therefore, we may have a basis for a *systems psychology* taxonomy.

A listing of the terms and colloquial definitions is given in Table 1.

Table 1. **Index of Information Processing Terms**[a]

MESSAGE - A collection of symbols sent as a meaningful statement
INPUT SELECT - Selecting what to pay attention to next
FILTER - Straining out what does not matter
QUEUE TO CHANNEL - Lining up to get through the gate
DETECT - Is something there?
SEARCH - Looking for something
IDENTIFY - What is it and what is its name?
CODE - Translating the same thing from one form to another
INTERPRET - What does it mean?
CATEGORIZE - Defining and naming a group of things
TRANSMIT - Moving something from one place to another
STORE - keeping something intact for future use
SHORT TERM MEMORY - Holding something temporarily
COUNT - Keeping track of how many
COMPUTE - Figuring out a logical/mathematical answer to a defined problem
DECIDE/SELECT - Choosing a response to fit the situation
PLAN - Matching resources over time to expectations of needs
TEST - Is it what it should be?
CONTROL- Changing an action according to plan
EDIT - Arranging/correcting things according to rule
DISPLAY - Showing something that makes sense
ADAPT/LEARN Making and remembering new responses to a repeated situation
PURGE - Getting rid of the dead stuff
RESET - Getting ready for some different action
GOAL IMAGE A picture of a task well done

[a]Twenty-five terms are briefly identified here, in the order in which they are discussed in the text. More complete definitions and examples are presented in the accompanying text.

Message

A task message is some collection of signs or symbols which have a meaning to the recipient—that is, have some potential reference to a task action or a context for action. A message is not a function, but the unit of information. Processing functions deal with messages.

In human communication, regularities in a class of messages lead to formatting (regularizing) their structure; that is, the constant factors become standardized in terms of their variables, sequence of variables, and other patterning factors that increase simplicity be reducing structural variability. This tendency is formalized in the use of paper forms that require only the variable information in a transaction to be entered. The operational advantages with respect to efficiency in composing, transmitting, and interpreting messages are substantial.

With repetitive practice in a given context, humans also tend spontaneously to develop formats for the reception of unformatted input data. The tendency to develop standard formats for the "snytax" of data is a highly useful aspect of "learning." The factors in a class of messages that can be formatted include: data categories, values of categories as a fixed vocabulary; sequence of categories; relationships among categories; standard message contexts; displays of messages. Even the operations of message redundancies can be and are formatted in practice.

The obvious liability in standardized format is the usual tradeoff of standardization and efficiency: loss of flexibility. If the content of a message does not fit the format, it is difficult to compose, receive, and interpret. The handling of exceptions may become unduly disruptive unless the message-processing system can signal an auxilliary non-formatted mode of communication.

The strategic design of message formats–and their reflection in training–seeks an optimizing tradeoff between the efficiencies of formatting "normal" communications and the adaptive flexibility of unformatted communications. A good paper format allows space for entering "comments".

Input Select

In psychological terms, input select means what is next noticed or paid attention to. It is related to the processes of scan and detect. The fewer the alternatives in message format, the more readily can irrelevant (to a given context) messages be rejected. Factors that influence message selection include perceived congurence with goal image; with prevailing set; with a hypothesis; with a demand for immediate response; and for immediacy of goal and closure. After a sense of closure, messages relevant to the preceding task will tend to be disregarded.

Habitual input selection structures, while necessary in degree for efficiency, have liabilities. Strategies embedded by training or used deliberately by the operator in operations consist of:

1. Having a mental map of the task cycle and mission well enough in mind that one can "tag" messages for contexts outside those of the moment.

2. On occasion, deliberately interrupting preoccupations of the moment to examine overall status, and thereby possibly modifying criteria of message relevance.

3. Learning that rapidly changing variables require more frequent sampling priority.

4. Remembering to relate status messages to strategic (longer-term) goals, as well as to tactical (short-term) goals.

5. Standardizing the maximum intervals when any message source will be sampled.

6. Scanning messages in advance of having to respond to them.

7. Sampling frequently when a resource of uncertain capability is used.

8. Collecting and grouping messages that build up the "complete" context for a response of large commitment.

9. Giving special priority to garbled messages.

It is of course possible to program training exercises in such a way that the operator is forced to acquire these strategies to compensate for the liabilities he acquires in processing "normal" messages and normal message sequences. But the operator must acquire sufficient facility with the normal operations that he has enough attention left over for coping with these interruptions to the ordinary flow of events.

Filter

Filtering consists of procedures which reduce or eliminate irrelevance and disturbance from messages and message contexts. What may be irrelevant in one context may, of course, be relevant to another. Filtering applied to messages (rather than signals) implies the screening out of classes of messages and message contents. The filter function overlaps nearly all other system functions.

The learning process spontaneously generates filtering: note the "object constancies" in perceptual set. Attention is a manifestation of filtering. Reading through heavy noise may require a special kind of attention and attention habit. The operator will have to depend more heavily on internal redundancy in the message and its context, hence, there will be a greater demand on his holding more information at a time in working memory. The greater the context, the greater the probability of useful redundancy in its content. But holding extended blocks of information in short-term memory calls for specialized practice. This practice should follow the operator's attainment of intermediate levels of efficiency in processing so that he has fairly well developed short-term memory formats for retaining transient data. Training should therefore direct the operator to be set deliberately to retain in memory more transient data than he is normally likely to hold. Especially under time stress, his normal tendency will be to forget transient data immediately after making a local response to it.

Various task strategies may cope with different kinds of noise. In electronic sources of signals, there is usually some gain value which optimizes the perception of the signal against a given noise background. Irrelevant detail (such as random perturbations) may be filtered out with the principle of moving averages—the integration of samples over time. Training should give practice in what to disregard (qualitatively and quantitatively), as well as what to pay attention to. The latter does not automatically imply the former.

Queue to Channel

These are rules and operations for organizing random message arrivals into "waiting lines" so that messages that belong together are grouped together. Restated, it is sequencing things to be attended to. The strategic objectives consist of getting the most context value from more or less heterogeneous collections of messages; also of minimizing the number and variety of changes in processing set-up and make-ready for collections of processing demands represented by varied kinds of inputs. Average processing delay time is another criterion variable. Succinctly stated, try to group those messages which demand the same continuing set to respond within limits of permitted operational delays and the fatigue of the operator.

Human tendencies are to process messages as they arrive, and especially during times of stress (a heavy load in the in-basket).

Organization of input data implies a look-ahead capability and the ability to classify messages in short-term memory according to a conceptual model of the operational process into which the operator's task fits. The operator should learn to process from a context of information and be motivated to maintain this level of awareness in operations. The competent operator sorts out messages that have high priority and can shift his prevailing set (processing schedule) quickly to accommodate without severe competition from on-going activities that may cause him confusion. Here again, the ability to hold a large amount of recent data context in mind enables rapid readjustment.

Where the operator has choice in sequencing his work, he should be given strategies that enable him to group demands that share the same tools, the same preparations and set-up, and the same context of within-task information. In training, he should learn criteria for rapidly attaching priorities to critical demands. He should seek to gain as much time between the appearance of a demand and the need to respond to it. This provides flexibility in scheduling for efficiency, in smoothing processing loads, and in adjusting to "emergencies." These continuous information-organizing (executive) activities clearly imply an active intelligence at work, rather than a docile transducer, and apply to digging a ditch as well as landing a crippled airplane.

Detect

Detection consists of procedures and mechanisms for sensing the presence of an action-stimulating cue from some background. It is often associated with a scanning process, and applies to natural and to symbolic environments. Operational variables include the scanning cycle and stimulus cycle; contrast between cue and background, scan pattern and predisposition to respond. Each of these factors gives rise to one or more strategies.

With extended experience, behavior tendencies tend to standardized scan and sampling format, standardized scope and range of scan and detect; progressive standardization of figure-ground sampling in a given work environment, reduced response to partial cues; projection of expectations. "tunnel perception" from over-practice, stress, fatigue, or distraction.

Training strategies can offset, at least in degree, each of these tendencies when they become habitudes, but only with the cooperation of the learner and his continued high level of arousal during operations. Scanning is for the most part internally stimulated, hence it is easily degraded and especially if aversive consequences are rare. Training may impart to the operator "models of threat"—a dynamic representation of the dynamic factors in a task that need to be sampled at some frequency and range in order to assure some probability of "survival" or effectiveness. Conversely, the operator may be trained with a "model of opportunities" to be scanned so as to increase his detection of potential options.

Another strategy is contained in scan redundancy before commitment to critical courses of action, or in response to a near-threshold cue. Other strategies can offset "blind habit," awareness of impariment,

stituation ambiguity, or personal stress. These strategies require the operator to learn to detect and identify when he is in error-likely conditions so that he can compensate for his liabilities by superceding his habitual scan procedures by deliberately-controlled scan behavior.

Skill at peripheral scanning is deliberately taught in many sports; many other tasks could profit from such training: operating vehicles is only one example.

Where large fields must be scanned for small objects- or where figure is difficult to differentiate from field- quite specific scanning strategies can be prescribed: interleaving; quartering; passes in more than one direction; with, against, and across the background grain or texture.

Unlike much of training which is directed towards coping with the normal and the anticipatable, scanning and detection competence has its objective in coping with the unexpected and the uncertain. It qualifies as a central function in many human competences.

Search

Search is a form of scan where the identity of the sought object is known. The object may be hidden in a heterogeneous field--like the needle in the haystack--or it may have to be discriminated from a field of similar objects - such as a face in a crowd.

Effective search is complicated by several human tendencies. One is the domination of previous experiences of location of the object; another is attractiveness of environments similar to those in which the object has been known. Searchers may be blinded by hypotheses about "where it *must* be." Searchers tend to follow random rather than systematic patterns. They persist in the same selection criteria (shape rather than color or texture, for example); and in familiar environments, fail to "see what is really there" the "Purloined Letter" situation. Often information context, like a deductive trail or a physical trail, that could narrow the search is neglected.

Search strategies are numerous. One is to search on the basis of the attribute of the search object that contrasts most distinctively to the search field and to competing objects. Another is to shift from one attribute to another in the search operation. A third is to use a scan mechanism, or modality, that enables the entire field to be searched most quickly. Still another is the use of information context for making inferences that narrow the probable area and search region. This last strategy, however, has the liability of all hypotheses: the assumptions may be wrong or incomplete. The strategic advantage of search by hypothesis as contrasted with random searching is that one generally knows when the test has been completed so that another hypothesis may be invoked.

Identify

One form of identification is the characterizing of a message by type or source. A more common usage is the recognition of an object or entity and the application of a label to it. The two parts of the process consist of discriminating the entity (and generalizing to its various manifestations) and making a reference action in retrieving its name. The process may be reversed so that given the name, the proper discrimination of the entity must be made.

The label of the entity can serve short-term memory as a mnemonic transcript and occupy "less space." It may be stored in alternative sensory codes: visual, verbal, auditory, kinesthetic.

One seems to learn "formats" for identifying individuals within a class of objects in an environment. When well learned, these formats serve as a kind of set such as recognizing French versus English words when spoken; identifying Oriental versus Caucasian faces, Russian aircraft versus USA aircraft. When identifications are overlearned, it may be difficult to recall the unique features of entities readily recognized when present. Expectations can lead to incorrect projections of identities. With overlearning, only those differentiating cues essential to the task transaction will be sampled; the others ignored. Identification learning can be facilitated by caricaturing the salient discriminating cues. The recall of the association with a label has a different reliability than making the perceptual recognition and conceptual identification.

If it is important that entities presented ambiguously or in noise must be reliably identified, a special training strategy is needed that requires the operator to attend to more cue dimensions than otherwise.

Behavior liabilities in identification arise primarily from inadequate cue-sampling habits. Stress may accentuate this deficiency. Blocks in the recall of names may persist despite substantial practice. A strategy for learning numerous identifications is to find and use key differentiators in accepting or rejecting hypotheses on identity.

Some jobs place great premium on rapid and reliable pairing of percepts and names. For purposes not only of communication but also for efficient short-term retention, training should provide ample practice that extends to conditions when the operator is heavily loaded. Such practice can insure reliability of identifications essential to the task. Thus, identifying map symbols, or names in lists, or parts and their names, or uniforms may justify far more practice than is normally given. Competence in identifications is not complete unless the operator can make them in the variety of contexts presented by the job. In some cases, this context may simplify, and in others complicate, the identification process.

Early in his experiences an operator may interpret a pattern of cues by a series of cognitive operations, whereas in later experiences he directly "identifies" the cue pattern. If time stress as well as reliability is demanded in perceptual processing, training should force, through repetitive practice, this shift from the interpretive to the identifying mode of response. The tradeoff, however, is that the automatic sampling shortcuts that help in identifying entities work against the more discriminating mechanisms of *interpretation*. The operator who merely identifies can be more readily deceived by appearances than the operator who observes and references a wider variety of cues. A strategy for overcoming this liability is to train redundant modes of observation, so that when the identifying mode may be inappropriate, the operator can shift to a set to "interpret" the cues presented to him. The latter calls for a different reference system in long-term memory.

Code

In this context, coding is defined as the rules for translating messages in one symbolic form to another symbolic form, presumably without loss of information content. Translating "15" to "fifteen" or clean input copy to output typescript are examples. Various codes have various liabilities and advantages for various purposes of efficency in transmission, in storage, in message composition, and in reliability of processing. The present section is mainly concerned with human transcription processes such as transmitting input content into its equivalent in verbal or manual outputs.

Several behavior strategies apply to the decoding of streams of input and encoding of output. One is to project periodicities into the input, such as grouping a long string of digits into groups of three at a time. Another strategy, subject matter permitting, is to apprehend meaningful groups of symbols of input for processing in order to facilitate retention in short-term memory. But this requires that the output encoding mechanism be temporally independent (at least in degree) of input rate. A practice strategy can accelerate the rate at which this temporal independence is acquired. The skilled typist of telegrapher reads well ahead of his hands. This temporal independence enables load-levelling so that fluctuations in the difficulty or rate of input can be smoothed out, and the output rate can remain steady. This load-levelling reduces operator fatigue and gives the operator channel capacity for adapting to minor perturbations in input without disruption.

With great amounts of practice, the operator's output comes from his *conceptualization* of the source input. With extremely high degrees of practice, even the conceptualization process can become transcripted and semi-automatic so that he may be able to converse while transcribing—if at less than his maixmum rate.

There are strategies for output rates. Output rates become rhythmic (and less demanding of effort, less subject to blocks) more rapidly if grouping of output elements is introduced early. In part, this requires temporal independence of output from input rates, so this independence should also be forced early in training. The learner's active cooperation in forced self-pacing is essential. In turn, this requires the learner to organize patterns of input more rapidly than he is likely spontaneously to do.

Task strategies apply mainly to problems that can arise in the input. He may learn to use message context to fill in garbled symbols with a risk policy to be made explicit. The operator should have special symbols for denoting uncertainty of source content. Getting set for a message context can minimize errors from adjustment to the new context. The operator should learn to adapt his standard output rate to the difficulties of unusual message content without breakdown. The operator may need to learn to adapt his

output rate to the processing rates of the device he is using for transcription. With some forms of complex input, he will be taught techniques for imposing or projecting systematic patterns so as to avoid overlaps or omissions. And he should be guided in the identification of combinations of input message elements to which he is error-prone so that he can anticipate a minor change of rate to accommodate to the special (although transcient) demand on his own information-processing ability.

Interpret

Let us treat interpretation as the rules and operations for translating the symbolic context of a message into a reference or meaning, usually by the addition of reference context from within the message itself or of reference context outside the message itself. It is responding to a group of signs, distributed in space and time, as a pattern. An interpretation is an inference about a condition or state of affairs or source of data. Some half dozen quasi-quantitative variables in the message content and in the operator's reference content make up the interpreting process. An "interpretation" enables the operator to reduce subjective uncertainty, organize intent and goal, and the selection of output activity; it can be both a form of decision-making and the content of decision-making. Thus, the hunter interprets footsteps in the snow; the reader interprets printed text; the leader interprets the enemy's intent as a prelude to a tactical decision.

Logically, if not psychologically, the product of an interpretation is a hypothesis about a state of affairs. This is a central concept for identifying the learning process and its acquired benefits and liabilities in the economics of performance. With continued practice to a class of "interpreting" situations, formats get learned: progressively fewer cues precede an "interpretation"; short-term memory is formatted for standardized cue variables; some classes of cues acquire greater priority and influence; recency effects obtain; mediating cognitive operations drop out; and depending on the subtleties required of response variation, a stereotyped and restricted repertory of "interpretations" sufficient for coping with task demands is established. Ultimately, the interpretive response in a class of situations becomes an "identification" response: efficient for processing but relatively inflexible.

Task strategies should derive from a combination of task requirements and the offsetting of behavioral liabilities. The range of work samples in training may expand so as to delay sterotypy; task relevant penalties and rewards reinforce the operator's treating an interpretation as a relatively tentative hypothesis. Training may induce the performance strategy of optimizing the "chunk" of data sampled in accordance with the unit of what is being interpreted. Key variables in making a class of interpretation may be learned and practiced. Operators may be trained in the "contemplative" pause - sometimes lasting only tenths of a second - before commitment to an interpretation. The search for classes of qualifying cues for differentiating interpretations may be part of formal training. The nature of the progressive unreliability of predictive interpretations, and thus the need for continuing samples to verify the predictive hypothesis, may be instilled in practice schedules. This latter point is significant in many tracking tasks where a good format for input sampling is essential, but does not always develop spontaneously.

Some tasks, because of their loads and because of the small range of discrete response outputs sufficient for performance adequacy, may require that the operator rapidly learn to *identify* a situational complex that as a novice he "interpreted." But other tasks may, on the contrary, depend on the operator's continuously enhanced enrichment and diversification of an output response repertory to match the large range of varibility in task situations. The respective training strategies must clearly differ: stereotype will be accelerated by time-stressing the student in practice; interpretive range *may* be enhanced by quality-stressing the output in temporally-relaxed practice.

Categorize

Categorization consists of the rules and operations for classifying objects, phenomena, data or intelligence, according to some one or more shared attributes, purposes or implications. The process overlaps identification and interpretation and memory. In general, the purposes of categorization are to generalize characteristics associated with some class of entities and for selective retrieval of contents in memory files. A categorizing judgment is made when a message is labelled by type and placed in a file in a file drawer. A categorizing judgment is also made when a decision is made to send a message to one agency rather than another on the basis of message content.

The strategy in the design of category systems consists of balancing the effort taken to classify the entity for storage with the effort required to classify a retrieval intention and to retrieve the entry from storage—and its relevant contexts. There are tradeoffs between the length of the descriptor list and the ease of discriminating entries with a set of descriptors. Hierarchical category structures can reduce the number of subsets (descriptors) to be discriminated by the operator at any given time; the liability is that the operator may misremember the hierarchical route. Zipf's "law" can be applied to the design of storage files: 80% of the accesses can be served by only 20% of the total file content.

With continued usage, the operator shows progressive tendencies in classifying input entities for a memory file (or activity channel) and classifying retrieval intentions. Fewer and fewer cues become sufficient for selecting a classification term. The operator becomes more dogmatic about his selection. He is influenced by preparatory set or context. His repertory of alternatives tends to shrink to limited selection sets, and he develops preferences for some classifying terms and subsetting schema over others. Training strategies and the initiatives of the operator can offset these tendencies.

Strategies for categorization are numerous. One is to deliberately design category structure for explicit *retrieval* intentions—the only practical purpose for setting up a memory file. Criteria should be specified for identifying members similar to other members in a subset. Classification rules should be made explicit and shared by all persons who enter content into the file or retrieve content from the file. If a hierarchical classification structure is used, it is imperative that the hierarchical rules be known and shared. If a coordinate descriptor technique is used, the rationale for dimensioning the descriptions of a file content should be explicit and applied in some amount of monitored practice.

Transmit

Transmission consists of the rules and operations for getting a message from one location to another. The present context deals with the transmission of meanings rather than of physical signals. This topic extends to message composition, as well as to the physical actions of outputting (transmitting) it to a person or medium.

With repetitive practice in a class of situation, the operator tends to develop spontaneously a relatively standardized format (syntactical structure) and a restricted vocabulary. Each variable about which data are reported will tend to occur in the same positional sequence in the message. Redundancies will tend to be eliminated. The operator will tend to disregard even available message feedback—unless it is a closure signal—and especially under heavy information load. Operators will attempt to fit classes of communication content *not* intended for the format into well-learned formats in a work situation.

The design of task strategies includes sender-receiver participation in the design of message formats that trade off ease in formulating messages with ease and reliability in receiving them. Different classes of messages may require the exploitation of somewhat different properties—reliability rather than speed, for example, or for ease in holding in extended short-term memory. The message format should be adapted accordingly. Where possible, a receiver should be "initialized"—prepared for a given message content, source, and context. (On the telephone, the caller's saying, "Hello, I'm Bill Roberts in Accounting" is an example of initializing the recipient of the call.)

If the human or physical channels may be perturbed, formal redundancy may be structured into message formats. It is important that sender and receiver share redundancy rules. Error-checking strategies can be introduced, but at some additional cost in processing function and time: segments of messages must be transiently stored and compared with reference criteria before acceptance; failing the test requires that a message demanding retransmission be sent to the source—which must also be prepared to return to the beginning of that message segment. Where a sender must transmit through noisy channels, he should be trained in the selective emphasis of factors that enhance the difference between the signal and its prevailing background.

Store (Long-Term Memory)

Memory is defined as the rules and facilities for holding messages and message content during indifinite periods of time for the purpose of retrieval. These include "rules" (or properties) for filing and

retrieval search. The contents of storage are information about data and information about procedures—although in the human this distinction may be arbitrary. This treatment is principally concerned with the role of memory in thought and awareness.

Some major tradeoffs in memory: task information may be stored and retrieved as a set of rules for processing task data; or it may be stored as a table of answers to specific situation parameters like being able to calculate square roots or memorizing square root values. The former takes more operational time and processing capability, but is more flexible: the latter is more rapid in operations, but occupies more storage space (i.e., may take longer to learn). Each is subject to a different kind of error: solution by calculation is subject to processing error; solution by rote recall is subject to recall error or failure. On the basis of the 80-20 axiom (20% of the content is used 80% of the time), some combination of the two methods may be desirable, both for training and for operations.

Another tradeoff is between parsimony in storage content (with rapid retrieval) versus richness (redundancy) in storage content. A procedure may be learned by rote, or it may be learned by a combination of rote and conceptualizations where the latter provide mnemonic richness called "meaningfulness."

In training, the principle of learning by contiguity can and should be extended from the physical to the conceptual: that is, when several *thoughts* occur together, the future occurrence of one of these thoughts will tend to elicit the other thought. This learning principle has significance in fostering the role of the student in his learning environment. Futhermore, the "code" of presentation of material to be learned will tend to be the same code which, when presented most efficiently and reliably, retrieves the content from memory. The code itself is a mnemonic content that clusters the content of what is stored. Unlike memory in machines, the code in which a memory content is stored may be functionally inseparable from the content itself.

Several training and operational strategies emerge. Training should be presented in the same input codes to the operator that will be presented in operations. If the operator must identify visual data in operations, text presentations will be *relatively* ineffective even though the operator can interpret the text literally. The text can be more effective if the operator can, while studying the text, translate its content into visual percepts. Even this process is less reliable than direct contact with the actual perceptual inputs of the task.

Although "intent to learn" may be a catch–all of various phenomena, it seems to be a significant variable for the coding of memory content. The training environment should therefore balance the student's striving to *perform* with his deliberate striving to *learn* to perform. The latter implies somewhat different attention habits and awareness which cannot occur if the student is overloaded continuously in practice by performance demands, and if his intent to learn as an active cognitive ingredient is not explicitly fostered.

Infrequently-performed procedures or procedures that may have to be performed under stress should be stored in redundant codes. Thus, one form of recall may be essentially perceputal-motor. A redundant form of recall may be self-instructed response in executing the procedure. A third form may be a set of images or percepts of the actions to take. Still another code may be an imagery of the processes underlying the procedure performed by the operator. These levels of encoding should be consistent with each other and operationally equivalent except insofar as speed and smoothness of execution are expected.

Training may impart mnemonic reference codes if the mnemonics are emphasized in practice. An example is the hierarchical arrangement of subject matter titles in a book which can serve to retrieve information in the head as well as in the book. If the hierarchy has a meaningful pattern in its own right, the items in the hierarchy can more readily be recalled all together.

Memory search may be helped by various strategies. One is to try various associative keys that get into the topic context: the greater the amount of associative content in awareness that is linked to some searched-for content, the greater the probability of retrieving that content. The visualization of part of the content helps towards visualizing the remainder of the content. Another strategy is search through deliberately-guided hierarchical references that may act directly as keys to the content being sought or serve to build context that aids in retrieving the sought content.

As a given memory content becomes frequently retrieved, the retrieval route becomes truncated so that the target content becomes elicited by the new context.

Just as format structures tend spontaneously to develop for the operator's internal construction of messages for transmission, format structures (equivalent to "file structures" in computer terminology) spontaneously develop for filing content of a given class into long-term memory. An overt task design strategy consists of deliberately creating the category structure for a class of "records" for storage and retrieval. In medical school, the standard format for learning about each muscle is: name of muscle; origin; insertion; action.

Short-Term Memory

Short-term memory, more appropriately called "working memory," may be defined as the rules and facilities for holding in temporary storage messages or parts of messages for use at later times during a task cycle or duty cycle or for combining with other information during the cycle. It is a key concept in information processing and a primary determinant of the operator's channel capactiy - the complexity of what he can process during a given time.

No doubt short-term memory has its manifestations not only in awareness but also in sub-awareness of which "set" is an example. The functional capability of short-term memory is greatly increased through practice of tasks in their operational contexts when the information it receives has been externally and internally formatted, coded, and transcripted. Functional capability of working memory is also increased when various activities that earlier in learning required self-instruction (or other mediating activities) become automatic. Instructional technique should be aware of individual differences in preferred codes for short-term retention: verbal, perceptual, kinesthetic, and so on.

Behavioral tendencies in the course of training consist of progressive reduction in sampling of the stimulus environment. This reduction in turn reduces the burden on working memory. It is also likely that working memory becomes more efficient in "forgetting" transient data after it has produced a response. The latter may be due to better "formats" developed in working memory for coping with regularized processing demands. A preferred code for the retention of short-term information will develop. Cues irrelevant to the task at hand will become disregarded. These may be called attention habits. All of this structuring is adaptive in providing the operator with increased functional channel capacity for coping with information "normally" experienced in the task. It is maladaptive when: the format is inappropriate; the sampling and erase functions do not apply to the situation of the moment; or interruptions occur to the "train of thought." Training exercises must therefore not merely sample representatively from the universe of task contingencies, but disproportionately in order to maintain operator flexibility.

Suitable training may embed several useful task strategies. One is forcing the operator to sample from cues ahead of the time he must respond to them. Providing the operator with anticipations enables some degree of operator self-pacing. Anticipations also give the operator time to retrieve reference information from long-term memory as required. Anticipations provide other behavioral advantages in freedom from external temporal tyranny. Short-term memory can be helped by a reference image of the major variables to be processed by the task so that a variety of data can be integrated–such as the percept of an aircraft in flight being fed by data from the various indicators. This is the operator's "picture of what is going on."

To avoid the liabilites of stereotypical processing, training should attempt to instill a wider range of alertness than the minimum generally required for typical task performance. The operator must sustain this alertness by his own initiatives. Short-term memory may be trained as the guardian against impulsive behavior occasioned by the dramatic stimulus. Training can accelerate the rate at which short-term memory filters irrelevance in input data–while striking a compromise with general alertness. Training may also attempt firmly to embed equivalents of goal images relevant as criteria for the adequacy of response at various stages in the work cycle. The alternative to the conceptual model of the task in short-term memory is for the operator to work from a rote model for emitting responses.

Since short-term memory is influenced by, and influences virtually all of the processing functions, the overlap of short-term memory strategies with other functions is understandable.

Compute

Computing consists of the rules and operations for solving arithmetic and mathematical problems having quantitative data or for the logical reduction of logical statements. Computing transactions consist of the following factors: the input variables and parameters; the processing rules or algorithms; the output variable or variables.

The present context of manual arithmetic provides many opportunities for errors in source data, errors in transcription of partial answers, and errors in table reference (arithmetic), transposition, procedure, algebraic sign.

Strategies for alleviating at least some of these kinds of errors include the following. Provide the operator with a conceptual reference for the operations he is performing and even for the data values that he uses. Provide him with a consistent procedure and format for a given class of calculations—and sufficient writing space for applying procedure and format. Train him to a highly "overlearned" ability to handle the simple arithmetic of addition and subtraction and in remembering the multiplication tables. Instruct him in techniques for making checks on his computation, preferably by a set of operations independent of those used in the first calculation; make these checks so habitual that the operator does not feel task closure until he has completed a check. Instruct him in the use of common sense in evaluating reasonableness of results.

To simplify calculational procedures, the results of which may be used in many contexts, instruct the operator in "pragmatic" precision; that is, calculating only to two or three places if the input data are no more precise than two places or if the output cannot be more precisely controlled than the equivalent of two place values.

Count

Counting consists of identifying an entity or unit and incrementing or decrementing a storage device and controller by the unit of magnitude.

Short-term memory is fallible in counting. Extended counting leads to mental blocks. But there are other sources of counting errors for some of which the following strategies are proposed.

When counting objects such as dollar bills or items on a shelf, make precise gestures in the itemization process. The gesture should have a standard timing relation to the utterance of the count. Separate and count separately those items that have different increments: count the singles, then the fives, then the tens, and so forth (or in the reverse order of denominations). Emphasize or underscore a vocalized count at regular intervals: thus, if counting by ones, emphasize "ten", then emphasize "twenty", and so forth. Maintaining a rhythm delays blocks and reduces confusion. Subset counting so that if an error is made, one need not start counting from the beginning, but may return to a known intermediate point in the count.

Decide

Deciding, by a loose definition, is the choice of a response alternative in a conditional situation. The nature of the choice-making has many variations, ranging from binary choice to either of two unambiguous signals to intuitive decision making at strategic levels of response.

The classes of information which enter decision processing include: (a) situation variables; (b) goal variables; (c) response alternatives; (d) choice-making policies or rules. In decision-making situations, there may be uncertainty in any one or combination of these factors.

Making decisions of a given class repeatedly leads to a more or less regularized structure and sequence of processing these variables. Goal variables become standardized and simplified and may act as constants rather than variables. Of many potential situation variables that might be sampled, relatively few remain operative, and these are sampled in a standardized fashion. The range of response alternatives will become restricted (other things equal) with limited search for new ones. Generalization of successful responses will occur, and not always appropriately. Implicit choice-testing will be reduced or eliminated. Depending on individual factors, such as aspiration level or catastrophic experiences, the process tends, with very extensive practice, to become relatively automatic. This has adaptive value for efficiency, but potentially maladaptive value for precision in choice, and for flexibility to changed situations, goals, response repertories and policies. Increases in regularizing and simplifying the decision process has continuing value up to some point, beyond which, in given situations, the process has liabilities.

Training for preliminary stages of decision-making should induce decision-making structure for apprehending situational data according to *regularized sequence* (if feasible) so that the operator can more readily retain in his short-term memory the essential conditions and circumstances of the given case. This may be the most important strategic training objective for early training.

The operator should again where feasible, learn the range of responses from which he has authority to select. This is, in part, job definition. Hopefully, this will not stultify innovative behavior which usually means the invention of additions to a repertory of response options.

Some classes of decisions can be segmented into a hierarchical or tree-like structure. A "yes" or "no" at any branch determines what next option is admissible. Not all decisions permit this kind of structure: most require responding to a map of variables which interact with each other. A decision-maker can learn a consistent sequence for the tree-like structure and become efficient in using it.

The operator may be given formalized training in getting situational data and in setting up priorities as to what data are most important to obtain in given situations. Not least in importance are criteria for determining when enough data have been obtained for making a choice or taking an action.

The operator requires both guidance and practice in choice-making policies or strategies. Such strategies may involve value-cost tradeoffs.Where uncertainty and risk may be involved, the decision is a *hypothesis* of the right action to take. Various exercises may yield information that tends to confirm or deny the hypothesis.

Note that this section is concerned with the training and psychological processes of decision-making rather than with external coping strategies such as statistical decision-making, game-playing, operations research, and so on. The present discussion on decision making can, of course, be greatly extended and amplified.

Plan

This is an important subset of decision-making. It is defined as the rules and facilities for predicting what future sets of conditions will occur and what responses to make to them, and in what order, so that given goals are likely to be achieved. It is the construction of an action path through a set of anticipated circumstances towards an intended goal state.

Planning may also be defined as the matching of a set of requirements to a selected set of resources according to a temporal sequence.

The planner usually works within a bounded domain of situation variables and resource variables. He therefore tends to develop with practice a conceptual format based on the consistencies of the organization in which he works or the environment in which he works. He learns (informally) the key situational variables with which other variables are highly correlated. By working primarily with the key variables, the planning is simplified, often enormously. If he is a realist, he also learns what the tricky contingencies may often be, and thus can prepare to offset their effects.

The behavior tendencies in planning will include all of those discussed under the topic *Decide*.

By demonstration and with practice, formal training can reduce the time required on the job for the student to learn the conceptual model will enough to think with it, and to apply the key planning variables and the key resource variables that enter into a domain of subject matter in planning. Learning to think with a conceptual model requires repetitive and varied practice. But a few hours of practice in acquiring and using a format for holding in mind and processing a pattern of information may be better than the equivalent of weeks of practice with material that the student has not learned deliberately to structure.

One strategic structure is the "critical path" concept which applies as well to informal thinking as it does to formalized projects. Several strategies apply to the selection of alternative resources- for example, versatility and mobility as factors. An excellent planner not only anticipates probable contingencies, but selects resources for them. Experienced planners may learn to allow, say, a 20% of budgeted resource for contingencies on a well-known type of mission, but may double that amount of reserve for a poorly known mission.

To the extent that planning deals with the unexperienced and unknown, it depends on constructive imagination. In training, it should not be assumed that students can or do use constructive imagination spontaneously

Test

Testing consists of the rules and procedures for deciding on the integrity or acceptability of a signal, message, or mechanism. As an operation it includes: sensing and measuring attributes of the signal; comparison with a reference value for the signal; decision as to whether the signal is in or out of tolerance; and an indication of that decision. The foregoing transactional variables indicate potential sources of test inadequacy, especially when a test is regarded as a *sample* of performance.

The operator will tend to omit tests under stress unless they are learned as integral to the "critical path" in performance. He will tend to limit the range of his test samples and tend to use only "nominal" input and output values, rather than test for range and variety of input and output. If the test indicator is not a Go; No-go device, but permits the use of judgment with qualitative criteria, the judgment will be influenced by "belief" and wishful thinking. The operator will tend to selectively test devices with which he has had difficulties and scant the others. The motivation of maintenance specialists to keep a professional integrity in their testing activity depends in part on their ethics (motivation) to "do it right" for its own sake. An awareness of this factor in training may enable reinforcing it.

In operations, a number of strategies are applicable. One is the collection, indexing, and retrieval of experience data that may serve as predictive data. A system may be checked out with a minimum number of tests by using data about its logical and physical pathways, connections, and dependencies. This principle extends to diagnostic testing where there are two major logical (as contrasted with empirical) strategies. One is the binary search or "half-split" principle. The other is symptom pattern analysis based on deductions from the sharing of good and bad outputs.

Training should attempt to mitigate the error tendencies that seem ubiquitous in empirical findings: the troubleshooter settles too soon on a hypothesis of what is wrong; he fails to look at symptoms directly available; he neglects positive as well as negative signs; he makes tests erratically; he is strongly influenced by his experience pattern, especially of dramatic instances; he repeats tests unnecessarily; he makes specific subsystem tests before general tests that justify them; he tends to be inefficient in setting up input conditions that will enable a variety of tests and deductions. Many of these tendencies would be diminished if the troubleshooter had a strategic model of procedure that guided his optimum sequencing of each next test to make that would—at a given stage of inquiry—give him the most information about the system's status.

Control

Physical control is the process of changing the direction, rate, or magnitude of a physical force that may be acting on objects, processes, or symbols. The stimulus may be embedded in a fixed serial order or it may consist of feedback test signals. Symbolic control is found in the source of instruction stating what will be done next with what facility.

The process factors in control consist of: signal of status, selection mechanism for eliciting an instruction that directs a change in some physical behavior; the mechanism that converts the instruction into a physical action or initiates a train of physical actions; the jurisdiction of physical actions which can be physically modified by the instruction and its location.

Behavior tendencies in control are manifest in many ways. Over control: this can be corrected only by the operator's learning to anticipate a condition and anticipate the corresponding effects of the system into which he exerts control dynamics. Out-of-phase control: often because of lag between the condition, the perception of it, and the control action, but learning a new control rhythm may be difficult and require extended practice. Unsuitably-graded control: may arise from operator preoccupation or having a limited repertoire of control sequences (such as "off" or "on," all the way); comes from inadequate guidance and inadequate practice which emphasizes study of feedback dynamics. Uncoordinated control often performing in serial what should be done concurrently; a manifestation of inadequate or incomplete training.

The most comprehensive task strategy is the principle: that control is best which controls least; that is, the fewer the changes in direction, magnitude, or rate of change that are introduced into an operating system–consistent with mission success–the more efficient will be both the control and the system behavior. This principle is so sound that it may be offered as one test of an operator's skill. The application of the principle necessitates that the operator anticipate the future environment, and anticipate the response dynamics of the controlled system to that environment.

Strategic control depends on sampling and integration of information about the near environment and the far environment; information about the response dynamics of the system to be controlled; information about the automatic adjustments and the tolerances of the system to perturbations to which it adjusts without the intervention of the operator's controls; operational "rules" or conceptual "equations" that relate the sampled environmental data to the control dynmamics of the system and to its capacity for automatic adjustment to minor perturbations.

Training in controls can be made efficient by suitably sampling from each of the above transactional variables and thus enabling emphasis on their respective contribution to system response. Training Strategy should also instill the operator's determination to keep on learning more and more about the properties of environments, systems, and controls by observing feedback and associating it with the environment and control actions that generated it. The operator should use operational feedback not only for operational control at the moment, but also as learning feedback to be applied to future cycles of operation.

Edit

Editing is applying rules for arranging and symbolizing information in messages according to prescribed formats. An example is a customer giving an order in narrative prose which the clerk translates into the content on an office order form.

After a high degree of practice in editing messages into output formats, the format tends to become a tyrant to what the operator will accept as input from an environment. Exceptions become rejected or force-fitted into the format. Furthermore, the editor tends to disregard components in the messages he edits that are not the subject of his formatting rules: he may disregard content even when common sense might shown it is important for him not to do so.

Task strategies should aim to provide the editor insofar as feasible a structure of output that is compatible with input structure and its variations. Thus, the waiter in a restaurant offers a menu in which classes of item are listed in the same order in which he sets down the order to the chef. Again where feasible, the editor should be enabled to cope with exceptional conditions not anticipated by his format: this may consist at least of a cell for entering a "comment." It is usually difficult for an operator to apply a number of rules at the same time, so he should be taught to sequence (where feasible) the classes of information to which editing rules are applied. Thus, editing a text for the meaning of its content makes it difficult to edit for typographical errors, and vice versa. Separate passes with different "set" (rule prepotency) should be made. If editing time is at a premium, the sequence should be prioritized from the most important aspect for editing to the least important–according to the recipient's criteria of importance.

Adapt/Learn

Learning consists of structural modification of the behavior of a system as the result of experience, where the behavior change carries over from one cycle of operation to another. Learning or adaptation may be shown either by some improvement in achieving an external quantitative and qualitative criterion or by some decrease in the system's cost in producing a given level of criterion output. In other words, a system exhibits learning when it increases a "benefit" or service; it also exhibits learning when it produces a given level of benefit at a lesser cost. "Control," by the way, consists of transient changes in behavior from applying existing programs; "learning" is defined as relatively permanent changes in quality or quantity of performance as shown in successive work cyles. (psychologically, the two processes are not independent.) Learning may consist of acquiring new functional relationships between system inputs and system outputs or it may consist of acquiring predictive relationships between Situations A and Situations B, or a combination of both.

One training strategy emphasizes the progressive building up of complex capabilities from component capabilities: the integrative strategy. Another strategy proposes successive levels of individuation of general classes of response levels to specific action levels. The former assumes that concepts are properly built up from behavior exemplars; the latter assumes that concepts precede and guide the formation of performance units.

Other contraries in training strategy center on the learner's role. In one, derived essentially from the conditioned response paradigm, the learner is regarded as a relatively passive device to be programmed by external schedules and manipulations of content. In the contrary view, the learner acquires and uses self-instructional operations, and it is primarily his moment-by-moment initiatives in the search and identification of relevant task inputs, outputs, and feedback that constitute learning. The learner may be given a transactional model of what he may aspire to and a variety of learning aids. The conditioned response strategy may be more efficient in formal training and less subject to problems of individual differences in learning. The cognitive strategy may be more costly in training time and facility, but enables the student to continue more effective learning when he is on the job because he himself has acquired the roles of both instructor and student. Probably a mixed training strategy will be most practical.

At somewhat more specific levels, the following principles apply.

Variations of task input conditions in practice will increase the reliability of the recall of task behavior to any of the sample conditions that may arise in the real work context. In other words, the generalization of response capabilities from training to the job will largely depend on the simulation of the sampling range of situations in the real job. This objective is a tradeoff against using a limited range of sample situations in training in order to obtain relatively high reliability of performance within that limited sample range.

A second general strategy in training is to attempt associative redundancy, or mnemonic richness. More alternative associate linkages between a task situation and a task response increase the probability of task response when the task situation is presented. Thus, tasks can be performed as rote programs, or as deductions from conceptual principles, or as verbalizations of procedures. The operator's ability to perform in any of these modes denotes mnemonic richness. A strategy will seek mnemonic richness at least within acceptable administrative cost, and this generally implies the active participation of the learner as a self-instructor. In order for the operator to serve as self-instructor, he should have a conceptual reference for selecting work situations, for choosing response, and for interpreting response feedback against a reference model. This may be summarized as the strategy of using the active (initiative-taking) mood of the learner, rather than his passive and receptive mood.

By providing the student with suitable goal image and the variables in the goal criterion, he may serve as a surrogate instructor with the special value of always being present when he performs. His advantage over the external instructor is in his ability to relate an action "hypothesis" to an action feedback.

Display

In terms of human tasks, "displaying" is the arrangement of messages into formats and symbol patterns for human perception and interpretation–structuring an intended meaning into a communicable representation. This problem is so broad that only a few strategic principles will be selected. (The entire field of general semantics and of logical fallacies can be referenced as applicable but outside the present scope.)

Behavior tendencies in free-form human communications include the following: omission of essential context such as the purpose or objective of the communication and its subject matter domain; details and mechanics of the content being stressed too soon; irrelevance to the domain and purpose introduced in subject matter and in level of detail; novelty in format rather than well-known formats of presentation being sought; cryptic symbols and nomenclature being used. These tendencies suggest the kinds of strategies that are applicable.

Task strategies in display of communications have tradeoffs, meaning that some situations call for occasional disregard of any principle. In general, the strategic objective is to communicate the maximum rate of meaningfulness relevant to an actual or potential purpose, objective, decision, or action by the recipient of the message. For example, charts, graphs, or maps can communicate a large amount of relation

information all at once. The principle is to initiate *context* in the message recipient and to extend that context. (The assumption is that "rational" content is being communicated.) A number of subsidiary principles follow from the general strategy of context initiation and building, where the criterion of relevance is providing the recipient with that information sufficient for him to take rational action.

Purge

The purge function is made up of rules for eliminating unwanted information. No design of a data base system is complete unless purge disciplines are specified. The concept of purge in terms of erasure seems inapplicable to humans. It does have applicability to the problem of the intrusion of responses that are incorrect in a new context. The difficulty shows in addressing Miss Adams as Mrs. Smith; of moving a switch forward, rather than backward, in order to turn something ON. When the metric system is officially adopted in the USA, we can expect difficulties in purging lifetimes of experience with the English measures of distance, weight, and volume.

Since responses are made not only to isolated "stimuli" but also from sustaining situation contexts, we quickly learn responses that, abstracted from their contexts, are incompatible. The learning strategy is to embed the new responses in new contexts, since mere practice in isolation of that context will have little effect. The dangers of intrusions from past learning occur when the new context is functionally absent; that is when the stimulus is in functional isolation from its new task context. This may happen when short-term memory is relatively unfilled with the new task context, such as when one is preoccupied or drowsy.

Shifting to the metric system will pose a class of far more difficult purge. We have a large body of percepts strongly associated with the old measures of inches, feet, and miles; or pints and quarts. These are reference judgments that are ubiquitous in daily life. Memorizing conversion tables will have little effect on these judgmental references.

The problem is to purge the old habits and judgments from the formation of new contexts. The correct strategy--at least theoretically--is practiced in some schools of foreign languages. During the entire time the student spends in the school, he is not allowed to speak a word in his native language. This tends to exclude at least the overt responses in the native language from intruding on the new language context. Furthermore, the student learns the language not by substituting the new words for the old, but in thinking with the new words.

The strategy for purging old contexts from their inevitable intrusion into new contexts is therefore to build the new context not as a conversion from the old, but as an independent entity from which the old is excluded as much as possible. When the new context is consolidated--that is, highly learned as a mode of thought rather than merely as rules and vocabulary--the operator may readily shift from one context to another with few or no intrusions after the first few moments in the shifted context. He has learned different response "sets."

Reset

In automatic systems, a reset may consist of emptying a counter of contents and returning it to zero; or purging a program no longer needed from foreground memory; or erasing working data no longer required. The second step in a reset is that of initializing the system for a new task; readying it with different programs and working data. Similar processes occur in the human when terminating a task cycle or shifting from one task to another. It is one of the guises which the term "psychological set" can take.

Inbuilt behavior tendencies facilitate the reset. The achievement of a purposeful goal or subgoal is accompanied by psychological *closure*, a kind of blanking of the mental registers of the preceding context. The advantages to short-term memory are clearly enormous. But there may be liabilities. The closure may occur before the operational requirements of the task have been completed: for example, documenting the action taken. Training must therefore ensure that the phychological goal is made coincident with the operational goal or subgoal, and this may be difficult if both goals are not perceived as congruent.

And time is required to reset. The greater the sense of closure, the longer the time to reset. The greater the new context to be initialized (brought into working memory), the longer the time to reset.

Work strategies are proposed to mitigate these liabilities. The idealized operator at the conclusion of a task cycle, but before terminating it, will review the events of the cycle for uncompleted activities. (Unfortunately, he thereby forfeits some of the enjoyment of dramatic closure.) As he nears completion of Task A, the idealized operator will think forward to the next Task B, thus beginning to get set for it. There will be a tradeoff in that short-term memory contents may spill forward and backward between the set for Task A and for Task B, so this strategy may be dangerous if the on-going Task A is imposing heavy loads on short-term memory. The operational advantage of rapid shift to the new task may be worth the risk.

The most effective strategy in task organization will be based on goal hierarchies, so that a minor closure may terminate a subtask, but at the same time that a higher-level goal acts as a control director for implicit initialization of the next task. This arrangement gets the best of both alternatives. It has an additional advantage. Because no closure is complete, the operator is capable of carrying over incidental observations that should be transmitted from one task context to another or from one cycle to another.

As a general design strategy for work, transitions from one work state to another are least effortful and least disruptive when they are mediated by anticipations.

The implications of these strategies for the design of training sequences seems self-evident. Practice conditions should, at some moderate levels of learning, provide the psychological glue that will bind part activities into a competence. The psychological glue is of three kinds: goals, contexts of information, and anticipations of what is to come next.

Goal Image

The operator's goal image embodies criteria for terminating a task or segment of work or mission, and terminating it with an experience of some degree of success or failure. The goal image is a mental picture of the conditions that should obtain when a task cycle is completed. Different goal images may apply to different levels of work activity. The goal image serves both a steering and power reference for moving from a present state of affairs into and through a projected route of action. Goal information is operationally meaningful insofar as the bahavior of the system is not completely rigidly programmed--that is, where the system has options for activity in mind and amount.

Behavior tendencies include the following. The student may be initially preoccupied by learning procedures and operations rather than goals and goal variables. With increasing degrees of practice, what may once have been a clear goal image deteriorates, and especially under stress and fatigue, and from repetition. A high degree of routinization induces the emitting of chains of behavior in an automatic fashion.

Where loss of goal image may be maladaptive, the operator can postpone deterioration by maintaining a continuously higher level of aspiration than his performance level. Training strategy should obviously emphasize and test the student's acquisition of goal variables and images of goal states that are realistic and reasonable for aspiration. The training situation may also demonstrate concrete instances of goal states that are barely acceptable (for given sets of circumstances) as well as goal states that are barely unacceptable. It is insufficient to limit these demonstrations merely to the orientation stages of training: they must be frequently reintroduced even into the mastery stages of student skill.

If the student is instructed in the tolerance ranges of goal variables, he can, if he is in the cognitively active mode, interpret task feedback and thus serve an instructional function for himself. But this function requires direction, opportunity, and encouragement. Ideally, the student will continue this activity after he terminates formal training.

To the extent that the operator has a clear picture of goal states, and is guided and driven by them, he has a basis for rational control over his own emotional impulses and his own tendencies for the expedience of the moment. The active control of a powerful goal image may enable the operator better to withstand stress, including periods of boredom. The indoctrination and refurbishing of the subjective goal image therefore has a continuing strategic value for operator performance.

Although these comments about goal image are generally self-evident, they seem not generally to be put into serious practice by specialists in the training and educational arts or by managers. Mechanized training procedures are especially prone to skip adequate training in purpose, goal image, and goal

criteria– perhaps on the assumption that the student, as a passive mechanism, can acquire these implicitly when he learns procedures and task formats.

In conclusion, the strategic objective for training the student in goal images and goal criteria is to make him cognitively active and aggressive as an operator, as contrasted with his being limited to passively emitting chains of responses that have been programmed into him. The operational "liability" is that he may be less docile to arbitrary external control. This liability will be counterbalanced by his more effective capability for behavioral change that will be required either because of new operational goals or because of new operational conditions.

Conclusions

The twenty-five functions described in this section encompass a large range of the transactions performed in an information processing system. Many, if not all, of these functions occur in any segment of systems work. The variations are in the proportional mix.

This means that in any comprehensive analysis of human work activities, a substantial number of these functions will be occasionally active. When observation or analysis reveals certain functions as critical to some set of operator work requirements, an examination of human tendencies in learning and performance can sharpen the selection from the foregoing pages of (a) a task strategy or behavior strategy and (b) instructional strategies for incorporating the work strategy into a reliable operator competence. This section of the report may therefore be considered as an enclosed and self-sufficient region for the analysis and application of strategy concepts to performance and training. It is intended to enclose a set of information-processing "primitives" at levels of behavior useful both for analysis and for training implementation.

The strategic assumption underlying this treatment is that the student or operator can and should be an active cognitive participant in learning and using work strategies. Justification for this fundamental strategy seems unnecessary, but means for implementing it need to be spelled out with a rich variety of examples and operational definitions. A more extensive data base on task strategies and behavior strategies would contain extended analytical definitions of these functions and many relevant examples.

The writer's preparation of this content convinces him that it can never be complete nor definitive in any logically rigorous sense. This certainly true of any class of information intended to serve the purpose of design. Task specification leading to "system design," and the training that incorporates task functions into a competence, comprise a *design* operation. It is always possible to improve the efficiency and effectiveness in the use of any potential resource, which in this case is the human operator. This improvement may stem from revised concepts about the potentialities within the resource itself.

IV. EXTERNAL WORK STRATEGIES

In this section we turn to the examination of work strategies that do not readily fit into a model of functions that make up an information-processing system. That system had a guiding reference structure: input processes; memory; processing operations; output processes. It dealt with symbolic representations of the environment in which the system operated and with the functional aspects of its own internal organization. But the strategies which may govern the physical interactions between the operator and his physical environment lack a simple structural reference.

This investigator failed, despite extensive work with a variety of conceptual approaches, to find a simple, logical structure from which to expand the development of external work strategies and thus to generate a basic structure to which additions could be referenced. In short, no structural principles for a taxonomy of external work strategies became apparent. Section IV, therefore, does not comprise a systematic treatment of topics: it is only a collection of examples. The writer believes he has developed a rationale which says, in effect, that systematic taxonomy, based on a few structural variables that are also comprehensive, is logically impossible or at least pragmatically unfeasible. This conclusion may be altered by a fresh set of assumptions about the subject matter.

Since it seemed impossible to develop a comprehensive reference base, a taxonomy, for external work strategies, it clearly became necessary to devise, in addition to a number of didactic examples, a procedure whereby training practitioners could analyze work situations and *invent* work strategies as required. This is the alternative to being able to reference some existing set of strategies already formulated. The procedure described in Section V is the result.

In the present report, therefore, only a few examples will be briefly highlighted.

An arbitrary, but often useful, distinction can be made between (a) strategies that increase the *effectiveness* with which a system copes with its environment and (b) strategies that increase the *efficiency* with which it copes. (Let us avoid the philosophical problems arising from differentiating "system" and "environment" by positing the system elements as comprising the operator and his prescribed work facilities.) Abstractly, the term effectiveness can often be treated as a "benefit", and the term efficiency can be associated with a "cost" for achieving a benefit.

In general, *effectiveness* can be increased by adding facilities, both for increasing a range of competence and for increasing the dependability of a given competence. The latter implies redundant facilities or operations. A second basis for increasing effectiveness is to make the history of a system's behavior available to it for learning purposes, so that it can better antiticpate environmental conditions and its own conditions that are related to them.

In general, *efficiency* can be obtained by policies that conserve system resources. One example is the standardization and formatting of frequently-repeated classes of transactions. Another example is the principle of minimal change so that groups of transactions are organized so as to minimize overall frequency and magnitude of adaptive modifications in setup.

It may be apparent that increases in effectiveness will tend to exact penalties on local efficiencies, and vice versa. The two variables are tradeoffs in the sense that accuracy is a tradeoff (within limits) for speed. The reader should recall that all strategies are constructed from tradeoff variables and at least implicit probability factors.

At a more concrete level, resources may be conserved in operations by minimizing change. More explicitly, the principle can be stated as: other things equal, minimize the number of changes and the rate at which changes are made, in kind, direction and velocity, while proceeding from a starting point to a goal point. By "other things equal" is meant "getting the job done as required." The application of this principle requires looking ahead and responding to an organized pattern of demands with a "plan." A good driver is one who, in identical traffic patterns, makes fewer changes in direction and velocity than the poor driver, while achieving just as good arrival time. This one principle is ubiquitous. It applies to space as well as to time; to the design of controls as well as to individuals. The general implications for training include those for the operator's look-ahead activity and for the organizing of variables going into a plan. The specific content depends on the specific context of work.

The titles of some less general examples of work strategy examined during this study include: developing or perceiving multiple options; drawing conclusions from data samples; use of musculature in work; working with the "grain"; using mechanical advantage; pattern-matching.

V. A PROCEDURE FOR DEVELOPING WORK STRATEGIES

The invention, and even the adaptation, of a strategy for a work situation is an inventive art. Procedural instructions may guide the acquisition and practice of competence in this art, especially in the analytic phases of it. But finally the essential insight depends on expertise and probably a substantial background of experience and familiarity with a broad range of examples of applied strategies. Finally, the practitioner requires a sense of realism in distinguishing the ideal from the practical in the operational and psychological worlds. He should also differentiate what may seem to him trivial in concept from the important in behavior and in operations. A high order of operator competence may consist of a collection of strategies, each one of which appears trivial when considered independent of the others. Thus, he needs imagination about processes to a greater extent than he needs purely logical facility.

As part of his competence, the practitioner needs a workable conceptual model of learning and performance processes consistent with the content in Sections II and III in the reference text. In practice, he will also need to acquire a conceptual model of the operations that are the subject of strategy development. He may have acquired the latter by having made task descriptions of the operator's work mission.

Information Processing Strategies from Available Reference Material

To the extent that the task and work requirements are expressed in transactional terms that can be identified by one or more of the information processing functions of Section III, it is possible to reference existing strategies directly. These may be incorporated directly into the design of task operations for training. Where the liabilities of behavior tendencies are to be avoided, training strategies may be adopted as proposed or modified. Because it is impractical to program the operator's every micro-activity, the practitioner will need judgment for selecting the more important from the less important material for formal design of training.

We now turn to the development of work strategies where reference material may not exist. This will consist of two major stages: analysis of the strategic problem and synthesis of a practical solution.

Analysis

A preliminary step is determining operating conditions where a strategy can be potentially useful. The following are guidelines.

Find any set of conditions where there are *multiple alternatives* that at a given time are reasonable to the operator and:

1. There is uncertainty about prevailing operational conditions.

2. There is uncertainty about the capability of a task resource.

3. More than one goal variable is to be compromised in a work optimization.

4. Efficiency or dependability or both are sought in the use or conservation of a resource or where some maximum capability of a resource is imperative to a mission.

Additional guidelines consist of the questions: Is trial and error good enough? Is the resource cheap enough to waste? Is the task motivation merely that of complacent survival as contrasted with "Let's do the very best with what we've got"? An affirmative answer to any of these questions implies that the potential strategy is not likely to be a winner, therefore not worth the trouble to develop and teach formally.

Contrast the following questions: Are errors in misjudging a state of affairs crucial? Is the resource precious? Is the motivation directed towards enhanced competence?

Analysis of the Operator's Mission

Assume that developing a potential strategy has been judged worthwhile. A crucial step is to determine what the entire job, or job cycle, is intended to optimize or satisfy. Rarely is this made explicit in job descriptions. Any statement longer than a paragraph is likely to confuse the central factors.

Now find a unit of work activity sufficiently large to have immediate and longer-term goal objectives. In some parlance this has been called a "work segment." Examples from maintenance consist of "checking and adjusting" and "disassembly and assembly" and so on. More recently, this investigator has formalized the concept of "duty module" which would serve this purpose.

With this background, we may now proceed with a summary outline of the steps in the procedure.

1. Abstract the transactional operation of strategic significance. This will consist of the concrete task objectives and the key transactions or operations for achieving the objectives. The structure for specifying a transaction consists of input state, process (including retrieval of reference data relevant to state and process), and output state.

2. Identify the dependent and independent variables in the task. (This step may have been partially completed in Step 1.) An independent variable is generally something the operator can observe or choose to do; a dependent variable is likely to be a consequence of the operator's action. The intent, at this point or later, is to determine if some policy can lead to better than a chance outcome. Another class of distinction may be made between the immediate outcome of an action choice against longer-term outcome of cumulative choices: the objective in strategy will be to tradeoff a localized benefit with a long-term benefit.

3. Begin with simplifying assumptions. Treat what may be secondary variables in the task situation as if they were constants—but bearing in mind that later, during the testing of the strategy, these assumptions must be changed to realistic conditions.

4. Make some extremely simple action models. These will be verbal descriptions or diagrams that relate, perhaps by question marks, the dependent to the independent task variables. The models may be simplified examples that incorporate the information generated in Steps 1 to 3. (A *transactional* model, not a mathematical model, is implied here.) Thus, the transactional variables for the pole vaulter are the rate he runs and how high he jumps vertically—where the magnitude of the first variable tends to limit the second, but where the vault is a joint function of the magnitude of both variables: the run puts potential energy into the pole, and the jump puts kinetic energy into vertical motion. Or the driver, faced with an imminent collision at high speed, may throw on his brakes or attempt an evasive maneuver, but he should not do both at the same time: change in velocity and change in direction are the competing variables—within operationally defined limits.

Step 4 completes the analysis phase of developing a strategy. The next phase consists of synthesizing the information gained by analysis into the invention of the strategy.

Synthesis and Invention

As in other forms of problem solving, the better the problem has been laid out—that is, structured according to criteria for a solution and problem variables—the simplier it is to arrive at a solution, and to recognize a solution when it appears. A strategic principle in itself is generally simple to state and to grasp in the abstract and is usually "self-evident" after it is stated—thus, redundancy in sending a message for reliability of message transmission; redundancy of facility for dependability of facilities.

The layout of the problem must depict a class of actions, or a given action in a variety of circumstances. The strategic principle will tend to appear as a compromise between a benefit and a cost, or between one benefit and another, or one cost and another. The principle may be perceived as a compromise between short-term objectives and longer-term objectives: that is, between task objectives and mission objectives. The principle may appear from inspection of the conditions of uncertainty and risk, or in a disproportionate difference between a given magnitude of outcome when it is a reward or when it is a penalty. One may shift one's thinking of a strategy as an action policy to thinking of a strategy as a planning format for making choices.

Each of the following steps may name a large amount of conceptual activity.

1. Induce or select the strategic principle. The applicable principle may be recognized by the structure of the analytic model, plus concrete transactional examples. Indexes to reference material on task strategies may be examined for possible synonyms. If an existing principle cannot be found or bent to the situation, the inspiration of invention is needed. The invention will come as an insight, sometimes after the standard psychological stages of observation, rumination, incubation.

2. Test the logic of the principle. A preliminary test of the principle is whether it is simple in concept and expression. Of course, poor or irrelevant strategies may also seem simple, so the test is not definitive. The logic of the principle is tested by trying to apply it conceptually to somewhat more complex examples than those used to generate the principle. The additional examples may, however, start a list of qualifying conditions for the hypothesized strategy. A rule-of-thumb is that more than two or three qualifying variables will make the principle psychologically awkward, so that the principle may need to be rethought.

3. Extend the principle into samples of real life. This step should lead to determining whether the constraints imposed by the assumptions made in Step 3 in the Analysis Stage lead to an impractical solution. The real-life examples are still handled in stimulated task conditions; if, however, some operator subjects are available *and* open-minded, some miniature pilot results can be obtained.

4. Realistically assess the principle. The question to ask now is: Is the principle good even if it is debased in practice? For example, does the principle have enough simplicity, operational value, and "growth potential"–in a statistical sense–so that it can survive indifferent and inept instruction, student inattentiveness and recalcitrance, and situational uncertainties? One can only guess at the answers. But with limited development and application resources, one should concentrate on likely winners.

5. Devise an instructional implementation. This is the second major step in invention. It depends on expertise in communication and instructional design, a quite different expertise than that of conceptualizing strategic principles. But the principle remains a useless abstraction unless it can be embedded in operator performance. Inevitably, the exigencies of instruction and performance will demand that the principle in application be only approximated. Instructional effectiveness will hinge on the skill with which approximations and compromises are made and communicated, because they will link the principle as an abstraction to the reality of operator competence in work situations.

6. Test the adequacy of the strategy. If the logic of the strategy is sound, the strategic principle as a concept cannot be empirically tested. What can be tested empirically is limited to one or a combination of the following: (1) the effectiveness of instruction in the strategy; (2) the relevance of the strategy to the task; (3) the relative importance of the strategic variables among the other variables in the task. If possible, the results of empirical testing, at least at the pilot stage, should identify which of these factors is the basis for a disappointing outcome. Pilot testing should first establish whether the principle is sound in that it *can* be successfully applied. Thus, one uses the *best* potential operators as subjects. A second pilot test may use subjects *representative* of the students and operators to be trained. This test will help determine if the principle and the instructional procedures *will* be used by the operator population and be effective. Success in the first test and failure in the second test implies a need for better instructional technique rather than a modification of the strategic principle iteself.

If strategic procedures must supercede habitual practices within an "operator culture," the phenomena of cultural resistance and cultural lag will be manifest. As a realist, the practitioner should be aware of these social dynamics. Members of the training institution may be especially predisposed to perpetuate the old culture. He must therefore seek to augment rather than challenge the interests and competences of technical staff and instructional staff. Successful pilot tests are insufficient to gain the necessary acceptance by the established social milieu and may be irrelevant or even hostile to acceptance. A fundamental strategy that is applicable to a wide range of task contexts may require a decade or more for assimilation into the training culture and therefore a reliable penetration into the "technical culture."

The practical test of the goodness of strategic principles therefore cannot be limited to experimental demonstrations. The practical testing must probe for acceptance by the instructional staff.

A final note of realism about procedures should be sounded. It is unlikely that the formal steps proposed for any problem-solving procedure are likely to be literally followed as stated, nor need they be. It is quite possible to truncate the half-dozen steps in the analysis and synthesis or invention stages of creating a strategy into a few moments of clear observation, lucid thinking, and sudden insight into a strategic principle. The purpose of a rational procedure is primarily to give beginners the opportunity to develop and apply exercise material and as a fallback when sudden inspiration fails to occur or to illuminate. A procedure tends to insure dependability in generating an acceptable product when the combination of sheer luck and talent by themselves have lapsed. But often a profound insight may be contained within a startlingly simple act of communication: for example, "That control is best which needs to be exercised least." Having made such a statement, one must now work backwards to the rationales and forwards to the applications which make the assertion a practical strategic principle in a real context.

VI. INSTRUCTION ON STRATEGY

The major objective of this study was the development of techniques and reference material for the design of strategies relevant to training and performance. Although training implications will be pointed out

below, no attempt has been made to show, systematically, how to convert a strategic principle into a plan and a content for training. In many cases, the conversion seemed fairly obvious. But the art whereby an abstract concept, such as a principle, becomes reliably integrated into an operational competence is not to be taken for granted. If the objective of the educational establishment is to teach a population to think situationally with concepts and principles, there is cause for concern on the state of the instructional art.

The present section is not a set of procedures, but a collection of explicit assumptions and cautionary comments stated in summary form.

The Student/Operator as Instructional Participant

It is assumed that training in strategies will be more efficient, more effective, and more enduring if the student participates cognitively in getting the principle into his performance. This cognitive participation depends, in turn, on an atmosphere in the training milieu that encourages student initiative in thought and action, as contrasted with pedantic dogma and mechanical practice of rules. Unlike a rule, a strategy will be effective only on a probabilistic basis. The student must have sufficient confidence in the instructor and in himself to accept the occasional failure of a strategy in a complex situation.

As a corollary, the student must have some confidence that his learning activity and his task activity can be guided by his thought. In this regard, a window cleaner may have more cognitive initiatives than a college professor–in the instance. Conventional measures of education and intelligence may have some correlation with frequency of cognitive initiatives in a work situation; clearly these factors *should* bear on the student's capability for the generalization of an abstract principle across a range of real life situations.

Except in undependable and rare instances, a strategy cannot become part of a competence if it is communicated merely by declarative sentences, like a proverb. It must acquire mnemonic richness by many examples and by application in the student's work practice. He must embody the principle as a *relatively* automatic guide in choice-making activity unless his task is artifically structured to require formal selection of plan and action.

Conditions of Practice

Some strategies can be learned and applied from a mechanical rule. Betting fifty-fifty on the toss of a coin is an example.

Other strategies must be learned and applied from a principle in the actual context of the task itself. Operating a vehicle or a tool are examples. Still other kinds of strategy interact so heavily with task information that they can be effective only when almost automatic, as in electronic troubleshooting. But even in the latter case, some cognitive rules will be essential to the operator during training and on the job.

The learning of decision-making strategies in complex situations can be made efficient by abstracting the decision-making aspect of the work and sampling widely from them. Ancillary procedures should be omitted from these exercises. This enables hundreds of practice cycles to be made on the strategic aspects of the work in the time that might otherwise be limited to half a dozen exercises in the full context of the work.

Strategies for coping with behavior liabilities and limitations must get extensive repetitive practice in order that they become automatic.

A sequence of stages for the instruction of strategies could follow this pattern:

1. A general picture of the task, its activities, environments and several examples of problem situations.

2. A description of the information-processing structure in the task.

3. Clarification of the variables to be optimized in performing the task.

4. The strategy stated as an optimizing principle accompanied by simplified demonstrations, preferably in the form of graphic displays.

5. Practical qualifications to be made in reaching decisions: the level of precision in applying the strategy adequate for practical purposes.

6. Student practice on highly simplified examples.

7. Diagrammatic representations of a variety of real examples.

8. Controlled progression to completely realistic problems, but symbolically presented. Then controlled progression into the physical context of the problems requiring the application of strategy.

Individual Differences and Testing the Learning of a Strategy

Large individual differences should be expected in learning and applying strategies. Some students will quickly grasp the principle as an abstraction, but be slow in putting it into practice. Since the application of strategy requires tradeoffs and judgments, no two students are likely to follow a given strategy in identical ways. And finally, students will have different aspirations for achievements. The absence of unambiguous criteria in tasks complex enough to justify strategies may foster these differences that will inevitably range from merely acceptable to virtuoso performance.

Despite these realistic observations, one can justify hope that the systematic inclusion of task strategies in training will shift the entire distribution of competence in a favorable direction.

APPENDIX A: EXAMPLES IN THE ANALYSIS OF TASKS FOR STRATEGIES

This section presents examples of strategic analysis in work situations. In no case is our analysis, either of the task or of strategic implications, exhaustive. The reader may question/argue the merits of individual strategy proposals, and these questions may lead to better strategies.

The intent here is to demonstrate–in necessarily loose terms–an approach and method for "discovering" where an explicit work strategy may be useful and how to create the applicable strategic principle. It should be emphasized that a strategy is really an hypothesis until empirically validated in the population of conditions in which it is intended to apply.

It is also well to bear in mind that strategic principles are generally the result of inductive operations, and often are (or once were) inventions. An invention is not the result of logical necessity. Where one individual may invent, another may ignore. Where one may create a highly context-bound procedure, another may create a more general principle. Readers may perceive more important and more useful strategies than those offered as examples in the following pages.

The examples included loosely follow the procedures described earlier, procedures that have been freely modified to suit expository simplicity and the particular problem under examination.

Strategies for a Parts Procurement Buyer

Work environment. A procurement clerk works in the development laboratory of an electronics firm. Relatively small numbers of parts are required for the development of engineering models, test devices, and so on. In some cases, a part can be identified precisely in a vendor's catalog; in other cases identification is not certain because some descriptive variables may be omitted. In still other cases, only a functional description can be given of the part required. The need for some parts can be anticipated weeks in advance. But often, components are needed immediately (if not sooner), and delay in getting them holds up work intolerably. With some exceptions, quickness in getting the part and getting the right part is more important than dollar costs, although where other factors are equal, costs sway a decision.

Work criteria for the procurement clerk. The work environment described above leads to the following broad criteria of the precurement buyer's operational job.

- The relative frequency that the part received is the part the customer wants or can use to meet his needs
- The average delay between the time the designer (customer) asks for a part and his receipt of that part, compared to the minimum possible or observed delay for equivalent orders of parts
- The average cost of the parts ordered compared with minimum possibie (or minimum observed) costs for the parts ordered

In general, the third criterion, although somewhat less importnt to the customer than the first two criteria, should not be ignored. Orders that exceed \$1,000 and have a lead time of more than 45 days are subject to vendor bidding, but our buyer normally does not process orders of that type.

What is NOT a criterion variable. It is not a requirement that this procurement buyer assess a product's dependability or the supplier's quality of workmanship. The buyer is given a list of suppliers whose quality of work is acceptable and he works within this list.

Granted that this is a somewhat artificial condition. It is presented to suggest the importance of specifying not only what variables should enter into the buyer's decision "model" but, in addition, the importance of specifying the variables he should *not* have to consider.

Organizational policy. Other things equal, and consistent with the aforementioned criteria, it is the firm's policy to distribute orders among a wide variety of suppliers. This policy is intended to reduce the laboratory's dependence on any single supplier or any small group of suppliers.

Work Flow. A highly condensed schematic of work flow would read as follows:

1. A need for a set of parts is perceived by a customer, typically an engineering group working on an R&D project.

2. The need is expressed and communicated by the customer to the procurement buyer, and a deadline for delivery is indicated.

3. The buyer determines what vendors apparently supply the part, reviews their catalogs, etc., and selects a vendor. He may communicate verbally with potential vendors by telephone or mail before reaching his decision.

4. The procurement clerk places the order with the selected vendor, including notation regarding delivery deadline.

5. The vendor confirms receipt of order.

6. As the deadline for parts ordered approaches, potential initiative is demonstrated by the buyer communicating with the vendor.

7. When the part is received, it is checked against the order and invoice.

8. The customer tests the part.

9. The procurement system received feedback from the customer indicating dissatisfaction/satisfaction with order.

Some data about these activities. The following data and work principles were supplied to the author by an old hand in a similar procurement job, a man who learned them by trial and costly error over a two year period.

Problem. The customer often incorrectly specified what he wanted, incompletely specified his needs, or implied irrelevant requirements. Delays, returned shipments, extra costs, and bad will between the suppliers and the electronics firm resulted.

Strategic Response. Get redundancy and context information in error-likely messages. The buyer almost routinely phoned the requester for information not included on the Procurement Request form. "Is the same part used in commercially available machines and if so, identify those machines." "What parameters are 'don't care' factors?" "What are the names of parts that would be acceptable alternatives?" "Given the 'when needed' date, what is the latest acceptable date of receipt?"

Justification. The more "exotic" the part requested, the more extensive the interrogation of customer by procurement clerk. The additional information gained in this way served two general purposes. It forced the requester to think through the identification and characteristics of the part he needed, thus better ensuring specification of what he really wanted. And, by specifying equivalences and "don't care" conditions, the buyer's available range of resource alternatives was expanded. (The requester was responsive to the buyer's additional queries because he got better service from him than from other buyers who did not bother him with additional queries once his requisition form had been submitted.)

Problem. The buyer spent much time calling suppliers who did not have the requested part in stock and who could not meet the deadline for delivery.

Strategic response. The buyer attempted to determine (from the requester and other sources) whether the needed part was relatively rare, and thus likely to be stocked by small specialty suppliers or by very large general suppliers. If relatively rare parts were sought, the buyer would first inquire from very large suppliers for two reasons: the better probability of their having the part in stock and the greater likelihood of their having an acceptable alternative. The buyer found his ration of successful to abortive inquiries considerably improved.

Justification. Other things equal, select a situation which provides the largest number of acceptable options.

Problem. A proportion of orders arrived after the deadline dates by which the vendor firms had promised delivery. Few vendors were consistent in missing delivery deadlines, or they would cease to be on the acceptable list. In many cases, however, delays of even a few days would disturb a project's work schedule/plans.

Strategic response. On particularly urgent orders (usually confirmed by telephone conversation with the requester at the time), the buyer would phone the supplier when approximately 80 percent of the total agreed-upon-delay for receiving the order had been reached. The buyer would remind the supplier of the deadline date, attempting to maintain friendly personal relations with the respondent. This was done most frequently with suppliers who were most unreliable--variable in failing shipping dates.

Justification. When there is uncertainty about when a message in a queue will be processed, the range of uncertainty can be reduced by moving the message into a higher priority in the stack. Attention brought to bear on the message increases the probability of its getting a higher priority.

Problem. In a proportion of shipments there were discrepancies between the order specifications, what the invoice specified as having been shipped, and the content of what actually was shipped and received.

Strategic response. The buyer insisted that when a shipment arrived, it immediately be opened and its contents checked both with the invoice and with the order. Insofar as was possible, the capability of samples of the shipment were tested to determine if functional specifications were met.

Justification. The closer to the event that a test of adequacy is made, the more precise, efficient, and effective can be the remedy in case of inadequacy. Direct comparison between what was needed, what was ordered, what was said to have been sent, and what was actually received enables relatively precise diagnosis if a discrepancy occurs.

Comment on the procurement work strategies. The novice tends to be a passive (although possibly diligent) transfuser of information in this job. The skilled incumbent develops a pattern of expectations and probabilities of exceptions (troubles), and develops strategic procedures for coping by active intervention with the major probabilities. He develops informal information "formats" which may backup the official formats, to increase precision of data acquisition, flow, and processing, and to introduce redundancies where he perceives the chances for error. He organizes his decision processes to a format of input variables and according to response options. He simplifies the process of making a decision--whom to call and in what order--by subsetting the options according to their respective success probabilities.

In this example, the following were indicators of potential strategies.

- A : undesirable proportion of communication failures (the first problem)
- The desire to maximize the range of response options (the second problem)
- The desire to better the chance of success in selecting options in the decision-making situation (the second problem)
- The desire to increase the proability of success in a processing operation involving indeterminate queue lengths (problem 3)
- The desire to minimize the propagation of errors from a potential error source, and to localize the error (the fourth problem).

I should also be recognized, however, that in most such cases, the exercise of the strategy is not without a cost. In perhaps a large number of cases, the order would have been placed and the part received as it should have been regardless of the lack of strategy application. In these instances, the additional work would have been an unnecessary burden.

In a pragmatic sense, if the cost of the errors made without strategic interventions is less than the cost of the interventions applied to call cases, then an inc rrect strategy has been selected, or incorrectly applied. That is, if the additional burden of work imposed on requester, buyer, and supplier did not statistically pay off, the buyer would be considered a busybody and a nuisance.

A strategy is an hypothesis based on assumptions and data. When the data no longer justify the assumptions, the strategy should indeed be changed.

Strategies for Disassembling, Inspecting, and Reassembling a Device

Work environment. A general repair shop which services a large range of light and moderately heavy–appliances made by many manufacturers is the environment. Most of the repair personnel have had some trade school background but relatively little experience on the job. There is minimum opportunity for detailed supervision and training on the job which is not generally regarded as being very permanent. There is high employee turnover. The repair shop has ample bench space for each worker and has a large collection of service manuals. In many cases, the repairman has never before disassembled or serviced the specific device he is given to repair–a chain saw, for example–although he may have taken apart and put together a number of power bench tools. The task does not include part reconstruction, (e.g., rewinding a fused motor coil). When reconstruction is required, the work is assigned to a specialist.

Work output criteria for disassembling, inspecting, and reassembling.

The following four criteria apply.

- Time to disassemble, inspect, reassemble
- Errors in assembly: parts left over, lost or misplaced; parts placed incorrectly in the assembly
- Number and extent of requests for help
- Functional operation of the reassembled device

Two additional criteria apply but these are "hidden." One has to do with the amount of practice time spent working on a given device. Other criteria equal, the less practice on a single type of device, the better because of the need for versatility in the shop. The other criterion, more deeply hidden, is relative lack of native mechanical ability which, aside from dexterity, would enable the worker to better visualize the working relationships of parts. These "incompetence" factors are not altogether unrealistic, and are intended to further justify work strategies.

What is NOT a criterion variable. In this atypical case, the bench space required for the job is not a criterion factor, within very generous limits.

Organizational policy. The high turnover and large varieties of devices to be repaired preclude specialization. When a worker completes a piece of work, he is generally given the next item in the work queue.

[illegible]erations and work flow.

1. Select maintenance manual (if available) from library or bookshelf: select and lay out tools in the work area. Assembly is done at the work area. Read applicable instructions
2. Disassemble [illegible].
3. Inspect for [illegible] integrity of operating parts for mechanical wear, using reference manual as guide.
4. Lubricate moving parts
5. Reassemble [illegible]

Testing of the reassembled part is done at another work station. The mechanic must accept occasional interruptions during his work.

Some data about these activities. The following observations were made and recommendations for improvement proposed.

Problem. Finding the right tool among the mass of parts and tools was a problem. After using a tool, the mechanic habitually put it down heedlessly anywhere in the work area. A sizeable proportion of time was spent in searching for a tool when it was again needed. The search not only took time but effort as well.

Strategic response. Develop a standard region in the work area where all tools are laid. After use, return each tool to the same place in this region. It requires some learning effort to remember to return the tool to its proper place after each use. This could be disturbing to the mechanic's preoccupation while he learns to standardize the operation. But this would be offset, even during learning, by the avoidance of breaking his preoccupation to search for a tool when it is needed.

Justification. Standardize the habitual actions of a task, especially where standardization will reduce search time and facilitate anticipations by the operator. The learning of standardized locations tends to be rapid and well retained.

Three additional problems. Searching for and locating the right part during reassembly was a problem. The mechanic habitually put down a part he removed wherever there was an open area. When disassembly was complete the work area looked like a pile of debris. A considerable portion of time was spent in trying to find the right part during the assembly procedure.

Another problem was that the wrong part was put into given positions in the reassembly, or a part was omitted. In some cases, parts that looked somewhat similar, but actually differed, were interchanged. The frequency of these errors and the rework they caused accounted for a substantial portion of the entire shop's cost for this operation.

Another problem was the most of the reference manuals available provided "exploded" views of the disassembled device. The mechanic found it difficult to relate parts in the pile of parts before him to the sequence of actions implied for assembly by the exploded parts diagram. Subassemblies were put together and then had to be taken apart because some step had been omitted.

Strategic response to these three problems. It was proposed that as each part was removed, it be put down in a reserved portion of the bench area, a place consistent with its location in the exploded diagram. If a diagram was not available, an equivalent layout of removed parts would be used. Where possible, the orientation in the assembly would be preserved when it was laid on the bench. (In teaching Army recruits the disassembly and assembly of weapons, the proper order in laying out parts is stressed.)

Justification. The justification has several parts. (1) Since the sequence of assembly is the reverse of that of disassembly, preserving the sequence of disassembly simplifies the reassembly operations. (2) The location of the parts is consistent with the order in which the parts are to be used in assembly, reducing or even eliminating the search for a particular part at any given time. It also reduces the likelihood of substituting a wrong part, or of overlooking a part in assembling the device. If a part is overlooked, it will soon be evident because it will be lying on the bench in an obvious position when the subassembly is complete. (3) The layout of the parts is consistent with the layout in the diagram thus providing a procedural reference between the instructions in the manual and the operations to be performed. A shared reference and orientation between plan and territory makes the plan more effective. (4) Anticipation facilitates work and convenience/comfort. The layout helps the mechanic anticipate what is to be done next. (5) Effort spent in putting information or material away in the form and sequence it is to be retrieved is compensated by savings in the retrieval operation.

Problem. Worn and defective parts were frequently overlooked during inspections. The mechanic inspected some parts as he took them out, some as they lay on the bench, and some during assembly. Sometimes, if a part "looked bad" when it was removed, the mechanic would set it aside and it would become lost.

Strategy response. The recommendation was to perform the inspections as a single class of operations separate from disassembling and assembling. When all the parts were removed, each part was to be inspected. Only one type of inspection at a time would be performed on all parts. For example, all parts would be inspected for wear, then for distortion (bent, shortened, and so on). The recommendation was sound in principle, but created difficulties. Wear in some linked parts is best perceived by excessive play when the part is in place in the assembly. A procedural tradeoff was proposed which recognized this factor, turned some risk back to the procedure, but was more practical.

The general principle was justified—attempts at standardizing the sequence of variables and minimizing dependence on short term memory for detour actions. (Inspection was a "detour" in the main train of thought—namely, rapid disassembly.)

Justification. The proposed strategy was justified since dependence on short term memory to instigate secondary tasks while performing what the operator considers a primary task risks errors in forgetting to perform the secondary task. The greater the preoccupation with the primary task, the greater the probability of forgetting to perform the secondary task(s). Performing each task as a series independent of the others may reduce errors, but this benefit may be offset by the additional manipulations required. The balance of this tradeoff depends on the level of competence of the operator—the more capable he is, the more likely he can effectively handle the more complex processing problem of removal and inspection at the same time—and on the relative importance of errors proportional to the time saved. Where even a few errors have high rework costs, the value of time saved by combining task operations becomes doubtful.

One might comment on motivation of the operator here. More "complex" task activities are generally regarded as more interesting (i.e., motivating) than simple task activities. The counter-argument is that making errors can be highly frustrating, and can lead to physical or psychological abandonment of a job. In this case, however, the disassembly operations were often sufficiently difficult to be challenging.

Problem. Mechanics forgot to lubricate the parts in the process of reassembly. Most frequently they forget the final, overall lubrication after completing reassembly.

Strategic response. Reindoctrination of the proper goal image for the job was proposed. The typical goal image of the mechanic was that of a reassembled device. Upon completion of the task he experienced "closure"—and was prone to forget task data. The recommendation was recognized as weak and probably ineffectual. If practicable, the final lubrication should be a "bulk task"—performed by some individual who does only this work on a series of completed assemblies.

Justification. As given above. Achieving a difficult and visible goal tends to make the operator forget task actions that should follow and properly terminate the assignment.

Strategies for Loading and Unloading a Delivery Truck

The following is an example of a "self-evident" strategy. Nevertheless, it is not necessarily followed by the novice, however self-evident it may be. Perhaps this is because "loading a truck" is one task with its own goal and "unloading the truck" is regarded as another task with an unrelated task goal. The situation emphasizes (like the example of the filing system) that putting things away and retrieving them are reciprocal aspects of a single operational (as contrasted with psychological) task.

Environment. Each delivery truck driver is responsible for deliveries in a general geographic area. He does not make pickups on return trips to the garage. His entire load is assembled on his portion of the loading dock. His manifest for the contents of the delivery includes a routing sequence for the delivery of the merchandise. His job, with the help of a loading assistant, is to load his truck and unload the correct contents at the designated addresses on the manifest and as stamped on each package.

Work criteria.

- Rate at which truck is loaded—total time used in the loading operation
- Amount that can be loaded on the truck (in almost all cases, the truck is large enough to accomodate the day's deliveries)

- Rate at which packages are unloaded from the truck at correct points of delivery (at some delivery points, penalities are imposed if the truck is parked more than a few minutes during a delivery)

- Proportion of items correctly delivered.

What is NOT a criterion variable. In this particular case, damage to containers and merchandise is not a factor. The goods are not fragile and the packaging is adequate. Where damage is a criterion variable, the packing strategy for the van would have to interact with the strategy proposed in later paragraphs. It would require that strategy to be modified to the extent that fragile packages would have to be put at higher physical levels in the load. This constraint on the loading–unloading strategy would impose limitations on the optimum to be achieved by the primary loading strategy.

Organizational policy. There is some pressure to clear the loading dock quickly. but this is not severe. An incorrect delivery is worse than failing to deliver on a given day, because the incorrect delivery causes annoyance to the person to whom the delivery is incorrectly made, a cost to the delivery company to pick up and redeliver, and annoyance at the delivery point because of the delay. In some cases, incorrect delivery results in the loss of the package and the filing of an insurance claim.

Operational work flow.

1. The driver (who also loads and unloads) is given the delivery manifest at the loading dock.

2. The driver loads the truck. He can get periodic help from a loading dock helper for heavy or bulky pieces. (He does not count the packages he loads to check and match with the count of pieces on the manifest because discrepancies are uncommon.)

3. He makes deliveries according to the sequence specified on the manifest.

4. At each delivery point, he opens the truck and after identifying the right packages to drop off, and checking the count with the manifest, leaves them at the customer's receiving dock. There is often intense competition among shippers for space at receiving docks, and there is pressure from the customer as well as other shippers to complete unloading quickly.

5. The driver continues to the next delivery point indicated on the manifest until deliveries are completed. He then returns to his home base for another load.

Some data about these activities. In this set-up, Step 4 seems to be the crucial one. The delivery company gets frequent complaints about the amount of time required for drop-offs. Some drivers seem to fumble around in the van, and even partially unload it, in order to find the items to be dropped off. There appears to be large variability among drivers in the average amount of time required for unloading and in number of delivery errors.

Problem. Reducing time and increasing accuracy in unloading. An informal inquiry among the better unloaders revealed one or a combination of two factors. The better unloaders (usually old-timers) were able to remember the address, appearance, and location in the loaded truck of a relatively large number of the packages to be delivered. This capability in their "working memory" was a clear advantage for the unloading operation, but it was not clear how new drivers could acquire this capability soon enough to improve delivery conditions to an acceptable level. Some of the better unloaders did not have a good memory. They spent a good deal of time in planning the loading task. Their strategy was as follows:

Put things into the truck in a sequence that is the reverse of the sequence for unloading the truck.

Following this strategy meant somewhat greater time spent in loading the truck, but this time was more than made up in unloading the truck. The strategy also meant that space in the truck could not be

used as efficiently as when packages were loaded according to a best fit arrangement. A tradeoff came to light:

The saving of time is often a tradeoff against saving of space, and vice versa.

In this case, optimizing for time in unloading penalized space requirements for given loads, but the value of time was more important than space, within certain limits. Space conserving strategies revealed the value of loading larger peices at the bottom of a stack and smaller ones higher in the stack. (This would also tend to reduce risk of damage to the smaller pieces.) The rational justification for this policy is that a large collection of small pieces permits more alternatives in arrangement to fit a given space than does a small collection of large pieces.

Problem. When drivers loaded according to the "first in, last out" principle, they often discovered that some packages that should have gone into the rear of the truck had not been noticed until the truck was almost completely filled. Either the truck had to be unloaded and reloaded (impracticable) or it was necessary to remember a "miscellaneous" group of items loaded somewhere near the front of the load (error-likely situation). A secondary strategy was developed that, if articulated, would be expressed in the following general form:

In uncertain conditions of requirements, hold back some proportion of resource as a reserve.

In this case, the resource was space in the truck. The loaders learned to leave a narrow right hand aisle when loading the truck. The dimensions of this aisle were somewhat larger than the average size package. This reserve space enabled a package that was over looked during loading to be moved back to its approximately correct location for unloading. Here again, we may notice that some space was used–or set aside for use–as a tradeoff against the time that might have been required for complete and reliable organization of the load of packages into the collections going to each delivery point.

Comment. The management of the delivery service was skillful in introducing these changes to their drivers. Expectedly, the major resistance came from those old-timers who had excellent memory for the identity and location of packages in their trucks, and who might follow the general principle of "first in–last out" but could remember miscellaneous placements of odd packages. These drivers held in contempt the somewhat elaborate procedures imposed on, and accepted by drivers who lacked this ability to the same degree. The resistance of "the elite group" with special talent was a major impediment to adoption of the revised practices.

Strategy in Setting Up a Filing System

Work Environment. Whereas research organizations generally have stability and permanence over extended periods of time, development groups in large organizations may often be ad hoc and relatively transient–existing for a period of between nine months and three years. If it is a high activity project, and the project interacts with a large number of other projects sharing related goals, there is inevitably a large flow of documentation. Documents include administrative memoranda and directives as well as technical reports and technical advisory publications. The distinction between administration and technical subject matter may often be blurred, but a rule of thumb is that administrative operations deal with money, deadlines, personnel, and the organization's procedural rules for doing business. Administrative memos are generally person-to-person or organization-to-organization documents.

A supervising secretary was hired for Project M. One of her duties was to "to organize the files" which were admittedly in bad shape. She was to design a workable filing system for all project documentation, both administrative and technical.

Work criteria. The following criteria apply to the secretary's filing system, *not* to the operations whereby she develops a filing system.

- Average time and effort (such as number of inquiries) required to classify and file a document

Average time and effort required to locate a document on demand by subject matter descriptors, document source, approximate date of receipt, or some combination of approximate date of receipt, or some combination of approximate descriptions of all of these. A modified form of the same criterion might be: The number of documents retrieved after a fixed amount of search time. The criterion applies only to the technical and administrative personnel, and their inquiries, in Project M.

What is NOT a criterion variable. It is not required that the classification system correspond to any formal library or organizational classification system, nor that the system be applied outside Project M. (This somewhat unrealistic qualification is provided to clarify the strategy for reaching a solution. If this qualification were not valid, the same principle would apply, but a secondary principle would be needed for adapting the solution to other file classification structures.)

Organization policy. Documents are to be made freely available to requestors, but a sign-out procedure is used to identify who has borrowed specific documents from the file. All memos and reports, even those that are addressed to an individual in the department, evantually become part of the organizational file.

Operations and work flow.

1. All organizational documents received come across the project secretary's desk.
2. Documents are logged in. Administrative items are separated from technical items.
3. Each document is assigned a serial accession number as received.
4. "Provisional" subject matter descriptors are assigned to each document.
5. A physical location code is assigned for position on the file.
6. The document is routed to project personnel. Project staff may add or change the descriptors.
7. The document is returned to the filing secretary, who checks the document against the receiving log and then enters biliographic data and physical file location of the document on reference cards and on subject matter cards for [illegible] The document is placed in the physical file.
8. Requests are made for administrative documents.
9. Requests are made for technical documents.
10. Search is made for the requested document and physically retrieved.

This work flow outlines the revised procedure, not the original one in which all documents were merely filed by the subject title given the document by the originator, and were then placed in folders arranged alphabetically.

Problem using the former procedure. There was continuous doubt about how to classify incoming material. Some documents carried two subject matter titles, or the titles were of the compound type. Finally, a simplified "rule of precedence" was adopted: Take the first subject matter word in the title or document that seems to fit. This rule also caused some difficulties, but the exasperated secretary found arbitrary responses that reduced anxieties.

Problem using the former procedure. Search by subject matter descriptor generally involved much time and frustration, and was less than 40 percent effective, even when the requester was quite certain the subject matter was contained in some document in the collection. Attempts to search the files according to subject matter became rare.

Strategy responses. The formulation of strategy requires a perception of operational objectives. The following rule applies: The only justification for storing information is to permit retrieval. (Although the rule may be self-evident, the practices it implies apparently are not.)

Strategy 1: Develop classification criteria and procedures to be applied to documents from the terms and subject matter descriptions used in retrieval demands. Contrast this strategy with its operational reference and empirical implications, to the generally vain attempts to classify by document "content." The latter is practically a meaningless aspiration since there are virtually an infinite number of possible ways to create and apply taxonomies.

The secretary who was charged with setting up a revised filing structure interviewed the staff members of Project M and, with patience, elicited lists of topic titles they were likely to request. These terms together became the starting list for classifying incoming documents. The list was modified as search requests were actually made, depending on whether the result was successful or otherwise.

There is, of course, a tradeoff between the effort made in filing and the effort required to find a document when needed. More effort spent in classifying the document before it is put away can reduce the effort required to locate it—if the filing operations are consistent with the retrieval operations.

There is another tradeoff in storage and retrieval. Organizing collections of subject matter where objects are grouped in physical proximity because they share an attribute is good for browsing purposes. This organizing principle may, however, complicate retrieval if some other attribute is the basis for inquiry, or if a document is precisely identified. In the latter case, a straight accession order sequencing may be more convenient. This raises a secondary issue in strategy for storage and retrieval.

Strategy 2: Separate logical descriptions of objects and their relations from actual physical location of the objects. Cards and indexes are more readily manipulated, organized, and reproduced than are phsycial objects. It is only necessary that the physical "address" of an object be included in the index card(s) which describe the object.

This strategy, aimed at minimizing object handling and physical activities, has its tradeoff since, for example, the preference for a given member of a set of objects may depend on observing and comparing it physically with other members of the same set.

Strategy 1 is generally applicable to information and communications viewed in a practical, task-oriented context. In effect, the selection of format, terms symbols, and other attributes that make up a message or set of messages should be derived from the intended use of the message set, and from the expected needs of the user or message recipient. The same principle applies to the construction of job manuals and work instructions, reference indexes, messages to computer operators, memoranda, and even technical reports.

Strategy for Visual Inspection of a Complex Part*

Environment. The work environment in this example is an inspection room in a large electronics manufacturing facility. Parts come from a fabrication process to be inspected, and go to an assembly process. Each part is a miniaturized electronic complex of circuits, components, and connections, fabricated at high cost. There is 100 percent inspection of these parts. Visual inspection is separate from functional inspection, and is the only topic of interest here. A variety of variables are involved in the visual inspection process.

The job had been done by specially selected and trained women. The selection process included tests of visual acuity, manual dexterity, and the ability to remain interested in precise but highly routinized activities for long periods during the work day.

*The author is indebted to Dr. Lance Miller of IBM Research Yorktown Heights, for this example. For proprietary reasons, I have freely paraphrased and changed some of the conditions of the problem which faced Dr. Miller, and I have also modified some aspects of his solutation to the problem; I have also omitted several factors which were part of the solution.

Criteria

- Percentage of defective parts identified during visual inspection. Later checks could not completely and objectively identify a failure in a visual check; the relationship between visual evidence of a defect and defective performance was only statistical.

- Percentage of non-defective parts identified as defective. Since each part had a high fabrication cost, rejecting good parts was expensive. Nevertheless, in case of doubt, it was more desirable economically to reject a good part than to accept a bad part. (If an economic analysis had been feasible it would probably have shown that passing one bad part cost about as much as rejecting ten good parts.)

- Time to inspect. Productivity was important, but accuracy was more important than speed.

What is NOT a criterion variable. No variable was uncovered that might have been considered important but turned out not to be important.

Organizational policy. In the original situation, each inspector worked out her own procedure for detecting defects. It was assumed, from the standpoint of motivation and of individual differences, that this was the preferred approach. It may also have been assumed that the complexity of the task did not lend itself to procedural specifications.

Former procedure. It should be noted that the job demanded that the parts to be inspected had to be viewed under a microscope. Training consisted of showing student inspectors samples of good parts and many samples of parts that were defective/unacceptable in one or more ways. Students learned to discriminate the sample bad parts from the sample good parts. After a 100 percent criterion had been reached in discriminating the good from the bad parts in the training samples, the student was put ot work inspecting actual components.

Some data about these activities. Some inspectors were good at detecting certain types of defect, but relatively poor in detecting other kinds. More precise tests performed on a sample of inspected devices uncovered an unacceptable level of correct inspections. The work was considered extremely fatiguing. Although the inspectors were conscientious and well paid employees, turnover was high. This inspection operation was becoming a critical one for the entire technology.

New procedure. A specialist in behavior and work operations was invited to study the problem and make recommendations. The ten criterion variables that could be discriminated by visual inspection were analyzed. A defective part was defined as one that failied any one criterion variable; the degree of defect on one of the variables was related to degree of defect on another variable. Samples of failure were obtained for each of these variables.

Students were taught a fixed procedure for inspecting the quality of one variable at a time (except for the interdependent pair), and each variable in a fixed sequence. The earlier sample problems included easily differentiable bad parts, and gradually included viewing of parts that just barely met standards and some that were not acceptable. The training included some forced pacing on each variable, although the student could (by pushing a button) easily request that the time cycle of a given variable be "replayed."

When a student committed an error, the sample was shown again for reinspection. Students were periodically tested to ascertain that the prescribed sequence was being followed for inspecting each variable in turn.

The students were allowed (but not encouraged) to give a "doubtful" rating. If a doubtful rating was given to a part, it was recycled through inspection. Measurements showed a marginal gain in valid inspections but barely within acceptable economic limits. The option did seem to give the student inspectors additional confidience in doing the job. In later training, the option of a doubtful rating was progressively reduced and finally eliminated as operationally unrealistic.

Human factors improvements were made. Microfiche viewers were made available at each inspection station. Multiple examples of marginally acceptable and marginally unacceptable conditions for each variable could be readily reviewed by each inspector without leaving the work station. The strategy represented by this change can be described as:

Comparisons are more accurate, in terms of average variability, when the test stimulus is judged with an absolute comparison standard than when judged against a relative reference standard.

Relative reference standards—e.g., those carried in the head—are subject to progressive change and are more readily influenced by irrelevant factors associated both with the test stimulus and with the response set.

This human engineering adjunct to the inspection task is not a "work strategy" in the strict sense, but does represent a strategic principle applied to the work environment.

Strategies applied.

- Format a multiple-variable decision process so that the operator examines each criterion variable and compares it with a criterion value in order to reach a pass-fail judgment. (Note that this strategy is applicable where each criterion variable is independent of the others—or can be made sequentially dependent as in the example described above. Where this is not the case and the operator must apprehend *pattern* as such, this strategy may be contraindicated. The alternative is a set to view the overall appearance.)

- Extend the procedural format to the examination of each variable in a standardized sequence, in order to minimize the risk of forgetting/ignoring one or more variables during the task cycle.

- Human automatization of a formatted task is hastened and made more reliable by forced pacing of elements in the sequence during later periods of training. (This forces the dropping out of time-consuming mediating behaviors, thus effecting automatized behaviors. Forced pacing—adapted to individual ability levels—also establishes a temporal criterion for rate of activities and level of arousal. Individual differences operate—those who spontaneously pace themselves at an optimum level are distrubed by external pacing. The training procedure should be sensitive to these differences and discontinue extermal pacing as when appropriate.)

- One way of measuring increase in skill in making a set of discriminations is to include in later training exercises those samples which the student failed at earlier stages in training. There must, of course, be enough cases to be reasonably assured that chance, or mere memory process, is not operating.

Comment. The analysis and procedural modifications to the task described above involved the investment of many thousands of dollars. Before final commitment, the hypotheses for improved procedures were tested on a pilot basis. Dramatic improvements in the inspection operation—both in terms of benefits and overall costs—had a high and continued payoff in the production line.

Brief Examples of Strategy Applications

The preceding examples have been accompanied by rather extended discussion. Those which follow are presented in brief. In the interests of space and patience, let us assume that similar analytic formats have been applied to each of the following problems, and merely summarize "problem situations" and recommended strategies.

Secretarial Activities

The novice secretary tends to take each piece of work as it arrives in the in-basket. She may file a report, then set up her typewriter for an inter-office memorandum, then set it up for transcribing an expense account. On completing the expense account, she may set up for a section of a statistical report, and on completing that task fill a request for stationery from the supplies department walking down two floors and a hallway to the supply room, and so on.

She seems to be busy during the entire day but, compared to some experienced secretaries, gets little work done. She is also criticized by her manager for failing to get to and complete critical and emergency matters right away.

Strategic principle. Organize the items in an input work queue so as to minimize the number of different work set-ups consistent with the time demands and limits imposed on getting respective outputs. A sub-principle: Periodically examine new inputs to a queue in order to detect high priority demands.

In practice, this principle directs the secretary to sort out the day's work into high priority and lesser priority activities, and then to group items of work that require the same or nearly the same set-up. Making a trip to the supply room is an example of a set-up. So is a filing operation. So is readying the typewriter (and the state of mind) for transcribing a well-defined structure for an administrative summary report, or for a technical memorandum. Psychological set-up (or simply "set") places demands on time and energy just as the physical set-up in a work environment does.

The same strategy is applicable to work queues in a repair shop, and to an executive's organization of his in-basket. The tradeoff in this strategy is boredom and fatigue arising from extended activities of the same kind, but these may be mitigated by the development of stable expectations in the daily work cycle.

Labor in Heavy Lifting

Teenage boys were hired for summer work in building construction. Much of their activity consisted of lifting and carrying lumber and buckets, and in moving filled wheelbarrows. Many of the boys became hopelessly fatigued after a few hours of work, although they were physically as strong or stronger than those who became far less fatigued. It was observed that many of the boys who tired quickly lifted objects and carried them in stooped positions.

Strategic principle. For heavy work, maximize dependency on the muscles of the largest size (i.e., the postural muscles in thigh and lower back, rather than shoulder and arm). Where practicable, a heavy object should be lifted with arms straight, back vertical or nearly vertical, and knees well-flexed. In carrying heavy objects, a second but related principle is applicable. Keep the load as close to the human's vertical center of balance as possible. Holding the object away from the body imposes unnecessary lateral strain both on the postural muscles and on supports to the grasping muscles.

Thus, a heavily loaded wheelbarrow should be raised from standing position with the arms held straight and the thighs doing the lifting. During the lift, mechanical advantage is obtained by standing near the end of the handles. As the barrow comes off its legs, lean forward, so that your weight is part of the force that imparts forward motion. While the barrow is being moved, keep arms straight, with hands slightly behind the hip so that the barrow is really pulled forward from the handhold rather than pushed. This consideration derives from another general strategy: There is generally greater directional control in pulling an object than in pushing it. (The tradeoff may at times be a penalty in rate control.)

Even minor violations of the center-of-balance principle impose much greater labor in lifting/moving an object. A long ladder that is lifted and carried at a point even slightly off its horizontal center of balance imposes large amounts of additional work to keep the end from dragging. If the ladder is being vertically positioned against a wall, deviations from the absolute vertical rapidly increase the force needed at the base to keep the ladder from toppling.

Inefficiency in lifting and carrying may not be significant in a few discrete operations, but multiplied by many activities repeated over a period of hours these minor inefficiencies may well sum into major fatigue.

Efficiency in transport is achieved by minimizing changes in direction and velocity. The veteran with the wheelbarrow tends to project his intended path from start to termination *before* he lifts the handles. Once loaded, changes in direction or velocity of movement become awkward, demand large amounts of energy, and are fraught with the perils of tipping. The projected path should therefore minimize not only turns, but up-and-down irregularities as well. The tradeoff, of course, may be a longer linear distance.

For variations in surface to be traversed, there are (within limits) variations in optimum speed of the wheelbarrow. Foward momentum can have a "load-levelling" effect on the human operator. Some energy is expended in moving up over a small rise or impediment and some is gained moving downhill. But, there must be enough reserve momentum to cope with momentary imbalances between energy lost and energy gained. The power demands are less on the human if the momentum is built up on the level or downgrade rather than on an upgrade.

Controlled Swing of Axe or Hammer

The novice axeman expends for greater effort and achieves far less accuracy and cutting results than the skilled woodcutter. Several strategic factors are involved in the preparation of the swing, in the force put into the swing, and in the control of the swing.

Preparing for the swing. The novice tends to lift the axe through the same arc in which it is swung downward. This requires that the heavy part of the axe is lifted at nearly maximum distance from the body's center of balance, and invokes a maximum mechanical *dis*advantage. The body must support both a horizontal and a vertical strain. The skilled woodcutter brings the axe close to the body and then lifts it, thereby minimizing the horizontal strain on arm and back muscles.

Making the swing. The novice exerts great force on the axe from the top of the swing. The skilled cutter initiates the swing with moderate force which is increased as the falling momentum of the axe increases. Thus he works with–takes advantage of–natural forces rather than against them. Perhaps the most general strategy to be applied: Where mechanical advantage is available, use it–don't fight it.

Controlling the swing. In tool-using, accuracy is at least as important as force applied, if not more so. This is certainly true in using the axe, sledge, or hammer. The unskilled person tends to maximize force throught the stroke by increasing the rate of the sweep. The skilled person seems to increase the momentum of the swing to perhaps two-thirds of the sweep and then *pulls* the tool towards the place it is intended to hit, making only small additions to its momentum. After sufficient practice with an axe or hammer one can sense a "right" relationship between swing and pull, and accurately anticipate where the tool will hit.

This relationship between the application of force and the retention of control is perhaps what is implied when a craftsman cryptically tells the novice, "Let the tool do the work."

Matching Patterns in Wallpapering

Good wallpaper is expensive, and so are the services of paperhangers. But, failure to properly match repeating patterns is a discomfort to the householder. The problem of matching without excessive waste of materials is especially acute in papering with the same pattern a first floor hallway, the wall beside the stairs, and a connecting second floor hallway.

The novice is likely to begin at one wall terminus and keep on winding his way around to the end of the surface to be covered. He will be in trouble most of the way and end with a botched job. The following principles are used by the expert.

Strategic principle. Give priority of appearance to the largest visual surface plane. This is likely to be the wall beside the stairs which connects the first and second floor. The start of a vertical repeat pattern should be up against the join of this wall to the second floor ceiling. From a strategic standpoint, this is equivalent to prioritizing the elements in a work "queue."

Strategic principle. In establishing a reference that will functionally link a number of pattern elements to each other, select the reference that itself has the largest number of direct links or connections to the set of elements which must be related to each other. Laying down the first strip of wallpaper is a highly strategic operation. The principle has general applicability where patterns are to be related consistently to each other.

In the case described above, the first strip of wallpaper was the longest to be laid in the entire job, extending from the top of the stairwell wall to the bottom of the stairs. It was made to lap around the wall in the upper hall, and to cut around and under the overhanging ceiling to the first floor hallway. Hanging this first strip took nearly half an hour. Once this strip was hung, a reference was established that was esthetically pleasing. In addition, this reference enabled three paperhangers to work simultaneously and consistently with each other, one papering the stairwell, another working on the second floor from the wraparound portion of the reference strip, and the third on the first floor hallway extending from the reference strip.

Cutting a Large Grassy Area with a Tractor Powermower

Consider a lawn area of two acres which is "broken" by trees, shrubs, a house, garage, driveway, and two partial outer perimeter fences. The mower tends to leave "sculptures" when it is turning in a radius less

than twenty feet. Thus, cutting around a tree or shrub requires considerable backing and filling, as does cutting along the irregular contours of planted areas.

The novice divides the job into sections, and completes the "trim" operations—around a tree, for example—as they are encountered in the cutting pattern. After completing one segment he goes on to the next. A major part of his time is spent in stopping, backing, turning, halting briefly going forward, halting again, and further maneuvering. The activity is hard on the tractor, uses much fuel, and takes a great deal of time.

A general strategy which could be applied here: The most efficient course is that which has the fewest changes in direction and velocity. A revision of procedure is planned. The new pattern enables the largest number of the longest straight cuts to be made. No trimming is done, except as incidental to a roughly parallel path, in the first part of the job cycle. A surprising number of long cuts are possible once "psychological" perimeters are considered. Broad turns are made that leave no "sculptured" grass. The edges of uncut grass are cut in a later trimming phase.

The trimming is relatively rapid because the mower can be maneuvered into an area in a position best for it to make the trim.

In one case in which the aforementioned strategy was applied, a total mowing task was reduced from a four hour to a two-and-one-half hour chore, and the finished job was better.

It should be noted, that the revised procedure was less satisfying to the operator. Opportunity for the sense of closure had to be deferred until the end of the entire set of operations. It was far more pleasant to complete the cutting and trimming of a "normal segment" of the entire job before going on to the next portion. This closure-seeking tendency leads to compromises with a procedure of known superior efficiency.

Strategies in Pole Vaulting

Dr. Frank Ryan, a professional psychologist at Yale University, has written a book on the essential strategies in pole vaulting. He lists the tasks as (1) Carry; (2) Run; (3) Advance of pole; (4) Shift of pole and body into final takeoff position; (5) Takeoff (a continuation of the run and source of added power); (6) Swing up in the air; (7) Pull, turn and pushoff. On the basis of a physical analysis of the forces and geometry of the problem, Ryan determined the ideal angle for jumping, and the best angle one can jump in running.

The advent of the flexible fibreglass pole used in place of the old rigid metal pole has changed the dynamics and strategy of pole vaulting. The bend in the flexible pole is able to store energy imparted to it from the run; this energy is returned by giving additional height to the trajectory of the jumper.

The principle is that the kinetic energy of the run is transformed into potential energy in the pole which is given back in gaining position—that is, height in the air. The faster the run, the greater the imparted energy for gaining height. A tradeoff in speed of running is the takeoff angle in the jump. The faster the run, the lower the possible takeoff angle. The closer to vertical the takeoff, of course, the greater the height. For any given runner, there is an optimum combination of these variables, assuming a pole with a given set of dynamic properties.

The combined effect of these strategic variables is to develop a maximum of kinetic energy which is usefully transformed into the potential energy for the lift.

Ryan's book is a model of task analysis and the application of strategic analysis and invention. It also has the assets of lucid style, brevity, and of focus on essentials.

It is perhaps ironic that rarely in the field of military or industrial tasks can there be found the intensive concern with task analysis, and both task and behavior strategy development, that is characteristic of athletics. The dedication and competitiveness inherent in sports makes this understandable. The objective of training is not merely acceptable performance, but the ultimate performance of which the individual is capable. If examples of the value of strategic analysis and training are absent elsewhere, they can be found abundantly in the sports arena. Even the likelihood that at least some strategies are effective mainly for "motivational" reasons is hardly a practical reason for rejecting them in a practical world.